TYPHOID FEVER

GEORGE C. WHIPPLE

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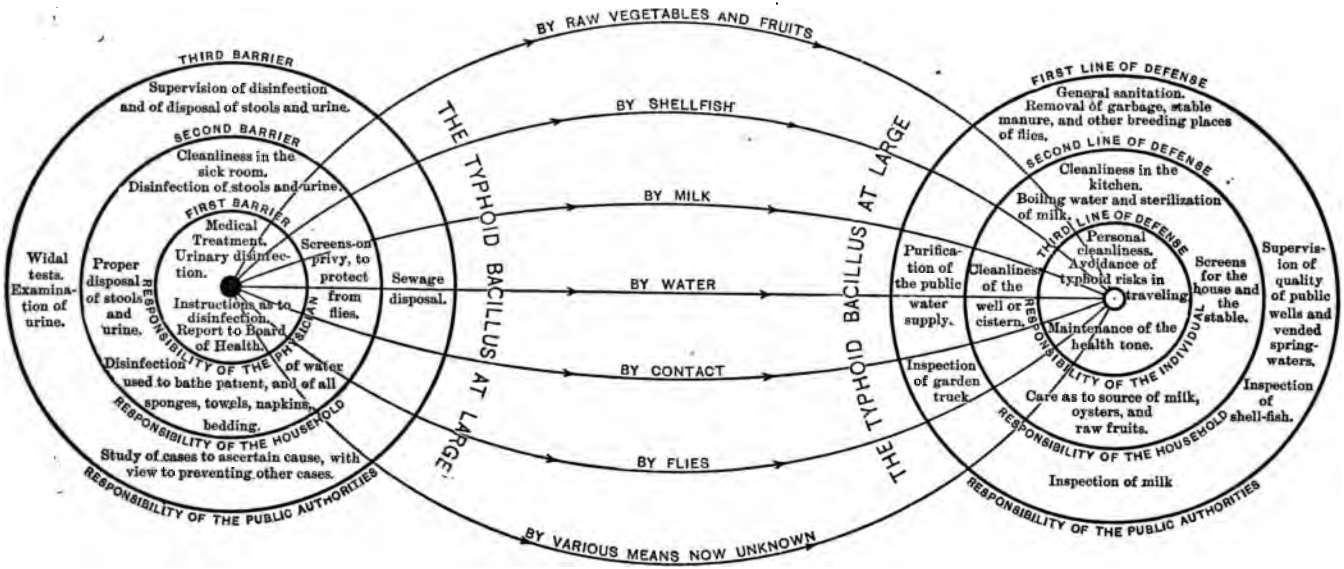
Henry F. Vaughan

TYPHOID FEVER

ITS CAUSATION, TRANSMISSION AND PREVENTION

TRANSMISSION OF TYPHOID FEVER

FROM THE PATIENT — TO THE VICTIM



AND MEANS OF PROTECTION

TYPHOID FEVER

ITS CAUSATION, TRANSMISSION AND PREVENTION

BY

GEORGE C. WHIPPLE

CONSULTING ENGINEER

WITH

AN INTRODUCTORY ESSAY

BY

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To

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

My Alma Mater

A PIONEER IN SANITARY EDUCATION

ENTITLED TO THE GRATITUDE OF EVERY ONE WHO VALUES

THE PUBLIC HEALTH

PREFACE.

FEW people, according to vital statistics, die of old age; almost every one dies of disease; and when your turn and mine shall come to shuffle off this mortal coil, we shall have the unwelcome and involuntary lot of more than two hundred different diseases.

The human body is a machine. Occasionally it is put together wrong; the various parts do not work in harmony. More often the machine is improperly operated; it is driven too fast, or it is given too much fuel, or not enough. Derangements due to these internal causes are termed "constitutional" and "local" diseases. There is another group of diseases which attack the body from without. They are the infectious diseases, or contagious diseases, parasitic diseases, zymotic diseases, as they are variously called. Alike in the fact that they are all caused by living organisms, they differ in many ways. The organisms themselves are different. Each has an individuality of its own, which the bacteriologist has come to recognize and to understand. There are differences in biological character, in habitat, in mode of development, in means of transmission, in the manner of attacking the body, in virulence, in longevity, in powers of resistance against remedial measures.

But the human body is more than a machine; it is an organism of living cells, each a living entity, and each working for the good of all. Invaded by cells from without, a mortal struggle takes place within the body. The enemy, though microscopic in size, and fighting with the aid of insidious toxins, has often been the victor; but, thanks to the science of bacteriology and its influences in the arts of healing and of public sanitation, the terrible ravages of the infectious diseases known in former days have been checked, and all along the line there has been marked progress in combating the bacterial foes. How great the value of the modern sanitary arts is to the welfare of the human race is seldom realized, yet the vital statistics published year after year are filled with proofs that diseases are gradually lessening and that the span of human life is lengthening.

Among the infectious diseases few are more dreaded by the general public than typhoid fever. Although less common and less dangerous than many diseases, yet because of its insidious invasion, its prolonged run of fever and prostration, its frequent epidemic character, and its too frequent fatal ending, typhoid fever has come to occupy almost the first place in popular thought among the diseases of mankind. People have come to recognize, too, that it is one of the preventable diseases, and that whenever a case of typhoid fever occurs somebody has been at fault somewhere. All this has naturally given rise to many misconceptions, — not only among the laity, but, unfortunately, among members of the medical profession. Many true theories have been overworked, many accurate bits of bacteriological evidence have been unduly exaggerated, unproven statements have been given currency, while some of the less technical but more practical matters have been undervalued or almost entirely overlooked. As an illustration of this situation we may take the current opinion of the nature of the disease, — its infectious character has been so much emphasized that the fact that it is contagious as well as infectious has been quite neglected.

The fight against typhoid fever must be made largely by men of two professions, by physicians and engineers. Differences in temperament, in training, and in the nature of their work have prevented these two professions from coöperating as closely as they must if typhoid fever is to be relegated to the class of infrequent diseases. The doctor naturally thinks of men as individuals; he is not accustomed to think of men in masses. The sanitary engineer, with his genius for mathematics and statistics, studies communities at large, and is in danger of neglecting to study the details of particular cases. The two professions admirably supplement each other. The engineer is by training the best fitted to control the measures which are instrumental in warding off the disease, to deal with matters of water-supply, sewage disposal, and the other sanitary arts; while the physician is best fitted to attack the disease in the household.

The object of this book is to furnish to the members of these two professions a condensed summary of the most important facts that have been learned regarding typhoid fever, so far as they relate to the prevention and spread of the disease; to furnish to the student of sanitary science a group of illustrations of some of the leading principles of epidemiology; and to give to the general reader a simple and, it is hoped, a clear and correct account of the causation, transmission and prevention of the disease, and his own responsibility in helping to bring about such conditions of cleanliness that typhoid fever shall soon cease to be a national disgrace.

New York, *April*, 1908.

ACKNOWLEDGMENTS.

THE author, being more familiar with the engineering side of his subject than its other phases, has been compelled to invoke the aid of his many friends in the medical profession in the preparation of this book. To all of them he wishes to express his thanks, and in particular to Dr. Herbert D. Pease, Director of the State Hygienic Laboratory of the New York State Department of Health; Dr. E. C. Levy, Chief Health Officer, Richmond, Va.; Mr. Francis F. Longley, Chief Chemist and Assistant Superintendent of the Washington Aqueduct Filtration Plant; and to his own family physician, Dr. A. Ross Matheson, of Brooklyn, N.Y.

He is also under obligations to many others, who, because they are many, must here be nameless, — to authors of various memoirs from which quotations have been freely made, sometimes, perhaps, with too scant acknowledgment; to health officers in many cities both in this country and abroad, who have contributed typhoid statistics; and to his nearer professional friends and associates who have given advice and assistance in many ways.

And, finally, to Prof. William T. Sedgwick, of the Massachusetts Institute of Technology, from whom the author received his first lessons and acquired his first interest in the science of epidemiology.

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INTRODUCTORY ESSAY

TYPHOID FEVER: A DISEASE OF DEFECTIVE CIVILIZATION.

By WILLIAM T. SEDGWICK.

TYPHOID FEVER is a discovery of modern civilization. When Queen Victoria was born, in 1819, typhoid fever was unknown. When she was ten years old it was just beginning to be recognized by a few pioneers as something different from typhus ("ship" or "jail" or "camp" or "spotted") fever, with which it had hitherto been everywhere confounded. When she ascended the throne, in 1837, it was still generally unrecognized, even by progressive physicians. In a report on the Boston census of 1845, published in 1846 by Lemuel Shattuck, an early and a singularly careful student of vital statistics, no mention is made of typhoid fever, but only of typhus; and it was not until after the middle of the nineteenth century that the disease became widely known in the United States, even to the medical profession. Its discovery, its name, its natural history, and the general recognition of its sanitary and economic significance, thus virtually coincide with the Victorian era, — a high tide in the history of civilization. It is still of frequent occurrence in large civilized communities as widely separated as

Paris and Pittsburg, as well as in a host of smaller but no less civilized places. It caused in 1906, for example, 253 deaths in London, 639 in New York, 370 in Chicago, 122 in Boston, 161 in Washington.

But while it is true both historically and as a fact of to-day, that typhoid fever is a disease of civilization, it ought to be clearly understood that it is only a disease of *defective* civilization, for it has gradually become notorious that the widespread or frequent occurrence of typhoid fever in any community must be due, somehow, to defective sanitation; and defective sanitation means defective civilization. It is also now generally believed that this disease, though specifically unknown, was really much more common and a much greater scourge of mankind before the Victorian era than it is to-day.

The broad outlines of the natural history of typhoid fever have now been known for more than three quarters of a century. The particular parasite or microbe which causes it has been well known since 1884, that is to say, for almost a quarter of a century, and the principal habits, habitats, and means and modes of transmission of the microbe, nearly as long. The experience of various communities, some large and some small, in first exterminating and then for the most part keeping off the disease, has demonstrated the possibility of its control. It is therefore impossible to avoid the conclusion that communities in which typhoid fever abounds are either ignorant or careless; and ignorance and carelessness are the ear marks of a defective civilization.

And what is here true of cities, towns and other large communities, is equally true of the smallest, which is the family. The appearance of typhoid fever in any family, even in one member of it, is likewise evidence of defective sanitation, although, unhappily, the insanitation which thus shows its dangerous effects may have existed, not in the household or the family affected, nor even in the city, town or village of which it is a part, but on some remote and lonely farm, or some distant fruit ranch, or at the bottom of some quiet harbor planted with oysters but polluted with sewage.

There is a fascination, a dramatic interest, in working out, even in imagination, the dark and devious paths and bypaths along which the microscopic parasites that afflict the human race travel to their appointed victims. Only the epidemiologist realizes the full meaning of the phrase, "the pestilence that walketh in darkness." All the skill of an expert detective is often required, — and often fails, — to discover the exact manner and the exact route by which typhoid fever was actually conveyed from one person to another; for while in some cases the way is clear and short, in others it is obscure and long. Those who read Mr. Whipple's account of various epidemics, notably that at Plymouth, Penn., in 1885, will perhaps realize in some measure what is meant by these statements.

It will be clear from what has already been said that typhoid fever is to-day universally regarded as a parasitic disease. A case of typhoid fever is probably as truly a case of parasitism as is a case of the itch, or of trichinosis, or of tape-worm; and the phenomena of the disease, or the sickness of the patient, are as truly the reaction of the organism to the attack of the parasite as are the galls of oak trees to the poison introduced by the gall fly, or the redness, pain and swelling which follow a mosquito bite to an attack by a mosquito, — that most familiar of parasites. In other words and from one point of view there is no longer any mystery about a case of typhoid fever. Each and every case comes somehow from some previous case. Whatever mystery there may be about it concerns the mode of transmission, — not the character of the causative agent.

And yet, in common with other contagious and infectious diseases typhoid fever was for a long time thought to arise spontaneously. Trousseau, for example, said

> " La spontanéité est donc un fait incontestable dans le développment des maladies, mème les plus contagieuses."

Murchison went further and in his popular "pythogenic" theory assumed that typhoid fever

> " may be generated independently of a previous case by fermentation of fecal and perhaps other forms of organic matter . . . it is developed by the decomposition of the excreta after their discharge."

To this last Dr. William Budd, of whom and of whose work more will be said beyond, pungently replied,

"To conclude, on the evidence usually assigned for such a belief, that a poison, of whose growth this is the history, is bred in every cesspool or ditch in which there may chance to be a heap of seething rottenness, is precisely on a par with the philosophy which led the ancients to believe that mushrooms are bred of cow-dung, alligators of the mud of the Nile, and that bees, as Virgil sang, may be engendered in the entrails of a putrid ox."

The rise of the germ theory of zymotic diseases and the discovery of specific parasites for the principal infections laid to rest the time-worn theory of the spontaneous generation of the poisons of the infectious diseases, and to-day the Eberth–Koch–Gaffky bacillus is everywhere regarded as the true parasite and sole exciting cause of typhoid fever.

Contrary to the views of some, the parasite which produces in its host what we call typhoid fever does not appear to be widely distributed in nature, if indeed it thrives at all "wild" outside the bodies of its hosts. The best proof of this is the fact that typhoid fever during an epidemic attacks very readily persons in poor health, the overworked, those who are run down and the like; and yet persons of this sort may and do abound in any given community for years without suffering from typhoid fever, while on the arrival of some traceable infection of food or drink by typhoid parasites they speedily take and suffer from the disease.

The parasite of typhoid fever also seems to be comparatively hardy. This at least is indicated by its frequent survival in water and milk, and its occasional occurrence in oysters, ice, air, sewage and elsewhere outside of the human body, which must probably be regarded as its most favorable habitat. For this reason it offers special advantages as a sanitary test or "sanitary index" of the general purity of food and drink as regards infectious microbes; the argument being that if this comparatively hardy parasite is absent, other infectious micro-organisms are probably absent also. If this one is present, it obviously matters comparatively little about others, since typhoid fever alone is sufficiently alarming. It is, of course, easy to show the inadequacy of this or any other single "sanitary index," since, for example, a milk free from typhoid has been known to cause hundreds of cases of scarlet fever. And yet it is roughly true that for any community which has constantly, year after year, a good record in respect to typhoid fever, the presumption is that sanitary conditions are at least fair. Strictly speaking, however, no such conclusion is justified, unless for the water supply, which, as far as is now known, is not, like milk, a ready vehicle of other infections.

One of the most striking and important of recent advances in our knowledge of the typhoid parasite is the fact that it appears to linger in the body of its recovered host, sometimes for months and even years, passing off from time to time in the excreta and infecting, or tending to infect, fresh victims. Every host is, of course, strictly speaking, during his illness a "typhoid carrier," but by common consent this term is now reserved for survivors from the disease and others who in complete health continue unwittingly to be a breeding ground for the bacilli and to discharge the typhoid parasites into their environment. There is nothing unlikely or unprecedented about all this, for we already have in fact though not in name, diphtheria "carriers," i.e., persons who have, or even have not, had diphtheria, and yet show its germs in cultures taken from the throat. If the time ever comes, as seems likely will be the case, when a determination of the presence or absence of the typhoid parasite in the body can be made as easily, and as accurately, as is now done for diphtheria, a great step forward will have been taken.

One of the first questions that arises when a case of typhoid fever appears in a family is whether or not the disease is contagious, and too often the family physician replies, "No: it is not contagious: it is only infectious." But in point of fact this question is as old as our knowledge of the fever itself, and has probably been the subject of more controversy than any other problem relating to the disease. When, for example, in 1829 typhoid was first clearly differentiated by Louis from typhus fever through the fact that the former alone is characterized by localized ulcers in the small intestine, that investigator noted that typhoid was contagious, though less so than typhus fever. Other workers alleged that one of the most distinctive differences between the two was that typhus was, and typhoid was not, contagious. The two diseases were so much alike that many denied that they really differed, and apparently the desire to prove them different led to an exaggeration of the difference in respect to their contagiousness. However this may be, the truth is that the contagiousness of typhoid has been almost always underestimated, and this in spite of the fact that Louis, who established the specific character of typhoid fever, Chomel, who gave to it its name, Bretonneau and Trousseau, in France, and Murchison and Sir William Jenner, in England, all asserted clearly and positively that it is a contagious disease. Chomel for example, observes (in 1834) that

"there is a great difference of opinion among medical men, — the majority in France denying every kind of contagion in this disease," —

their principal reason being, apparently, that of those surrounding the patient only a few take the disease. Chomel concludes that though plainly contagious it must be less contagious than many other diseases.

Sir William Jenner, about 1850, after a careful study of typhus and typhoid fevers wrote: —

"If typhoid fever be contagious it is infinitely less so than typhus. My experience leads me to regard it as contagious."

Dr. Murchison, in 1858, gave it as his opinion that

"typhus fever is eminently contagious. Typhoid fever is also contagious but in a more limited degree and possibly through a different medium."

Four years later he affirmed:

"It may be communicated by the sick to persons in health, but even then the poison is not like that of smallpox given off from the body in a virulent form, but is developed by the decomposition of the excreta after their discharge. Consequently an outbreak . . . implies poisoning of air, drinking water or other ingesta, with decomposing excrement."

Thus matters stood when, in 1873, the splendid and convincing work of Dr. Willliam Budd, an English physician, appeared, and proved beyond the shadow of a doubt that typhoid fever is a decidedly contagious disease. No student of typhoid fever should fail to read this remarkable volume and to make thereby the acquaintance of a master of keen and minute analysis and vigorous inductive reasoning. Tyndall has referred to Budd as "a man of genius withdrawn from the stimulus of the Metropolis and working alone at a time when the whole medical profession in England entertained views opposed to his."

Budd's position was so strong that Professor Tyndall, whose ability to weigh evidence will hardly be questioned, was fully convinced and in 1874 wrote a strong letter to the *London Times*, saying,

"How could a disease whose characteristics are so severely demonstrable have ever been imagined to be non-contagious? How could such a doctrine be followed out, as it has been, to the destruction of human life?"

Dr. W. H. Corfield in 1874 went further, declared typhoid to be "virulently" contagious, and explained the differences of the contagionists and the anti-contagionists as follows: —

"That it is contagious, and most virulently so, I have not the slightest doubt; but I quite understand what those mean who say it is not; they mean that if you attend upon a patient suffering from typhoid fever you are not likely to get it, while if you attend on one suffering from typhus or scarlet fever you are very likely to do so, unless you have had the disease before; they do not consider that this fact is not due to a difference in the contagious nature of the disease but to a difference in the form in which the poison is excreted from the patient, most of it being in the one case given out into the air which the attendants breathe, while in the other most of it is swamped in a mass of liquid which is removed as soon as possible. Those accustomed to smallpox, scarlet fever and the like, of course, said that typhoid fever was not contagious, when it was first brought to their notice, and there is no doubt that it is, under ordinary circumstances, very slightly so in their limited sense of the word; but that is not what is meant by those who now deny that, except under certain circumstances, it is not communicable from one person to another."

I have dwelt upon this matter at some length because the true contagiousness of typhoid fever is, even to-day, not recognized or taught as fully as it should be. No one pretends that typhoid fever is as contagious as smallpox or scarlet fever, or perhaps even as diphtheria. Doctor Corfield in the quotation just given has well stated the reasons why; reasons which, though formulated before the germ theory had been proven or the microbic parasite of typhoid fever discovered, are no less sound to-day. With the rise of that theory and the discovery of the parasites of the principal infections; with the brilliant achievements of epidemiology and the novel and startling discoveries of the rôle played by polluted water, polluted milk and other food materials, such as shellfish; with the astounding revelations of the damage done by insects as carriers of malaria and yellow fever and plague; the humbler, more insidious, and less spectacular part played by dirty hands, soiled linen, dirty bedding, dirty towels, dirty dishes, dirty forks and knives and spoons, dirty toys or playthings, dirty pencils, dirty candy or similar objects, handled or mouthed or kissed or sucked or spit upon, by persons having typhoid fever, have attracted but small attention. Yet it is to direct infection of this sort (which is what we mean by "contagion") that we probably have to look for a large part of that residual typhoid which still clings to many communities even after the water supply has been purified, the milk supply cared for and the various other public supplies controlled. There may have been a time previous to 1873 when a well informed physician in order to calm the fears of a family having a case of typhoid fever could have said conscientiously, "You need have no apprehensions for the rest of the family; typhoid is not contagious, it is only infectious." But since Budd's great work, no scientific man, at least, would have dared to say as much. Those who depend on any such statement are living in a fool's paradise, for to-day it is a well known fact that even trained nurses in attendance on hospital cases where safeguards abound are often unable to escape an infection which is practically contagion; and this in spite of abundant knowledge, frequent warnings, and some painstaking. They may not have caught the parasites by touching their patients. They may have touched the patient's contaminated clothing, or bedding, or food, or utensils, or excreta. But between an infection so direct and so short-circuited and that which comes from actual contact with the person of the patient, there is no essential or important difference; and it is a satisfaction to one who, following William Budd, for years, and sometimes in the face of adverse criticism, has taught that typhoid fever is a contagious disease, to find that fact now more generally admitted, and even made popular among physicians by so good an authority as Conradi.

"Twenty years ago I received letters describing to me the grief and ruin introduced into families through the notion, then prevalent, that typhoid fever is non-contagious. When Dr. William Budd published his researches on this subject, showing by facts and reasonings, as cogent as it was in the power of science to supply, the infectiousness of the fever, certain writers discerned in that important work a proof of the decadence of Budd's intellect and gave the public the benefit of their conclusions." (Professor Tyndall, *New Fragments*, p. 428.)

One very disagreeable fact about typhoid fever is that it is intimately associated with human excrements. Diphtheria parasites are probably cast off chiefly in the sputum. Bacillus tuberculosis, according to some recent ideas, is given off freely by tuberculous cows in their milk, their sputum and their excrement. But since the lower animals do not have typhoid fever, man is the only source of the peculiar parasites of this disease, and though the germs may occur in the spit and sweat it is believed that they occur most often and most abundantly in the urine and feces of typhoid fever patients. Hence it follows that if water, milk, oysters, etc., convey these germs, they have probably been contaminated by human excrement. Such contamination often arises by the way of sewage pollution of foods and drinking water supplies. But if the recent discoveries relating to typhoid "carriers" are correct and logically interpreted, they indicate a more direct, more personal and more disgusting contamination of food and drink by servants and others of unclean habits, and compel us to assume an easy transfer of filth from one person to another through contact of excrements with food or drink.

To overcome this disgusting condition, which is far too common, nothing will suffice except education in personal hygiene or, what ought to include this, careful home training. Sanitation can effect the purification of public water supplies, but it cannot either induce or compel waitresses to wash their hands before passing from the water closet to the china closet. This, only education or training can do, and until they have done it, unclean servants will continue to be what they are to-day, a serious menace to personal and family, as well as public, health.

The statement is often made that "for every case of typhoid fever some one ought to be hanged." It is a striking saying and worth remembering, because it puts the responsibility for this disease where it belongs, namely, upon mankind, and not upon fate or the gods. But, unless hanging is to be introduced as a penalty for ignorance and neglect, it is not often true. What is true is that *every case of typhoid fever comes from somebody's ignorance or neglect.* And here also the remedies are education and training, with penalties only for criminal negligence. We might more truly say that for every case of typhoid fever some one ought to be educated.

And just here Mr. Whipple's work is certain to do great good. Itself a remarkable witness to the variety of interests concerned with or affected by typhoid fever, it is important also as a demonstration of the intimate relations already established and to-day rapidly increasing between sanitary biology, preventive medicine and sanitary engineering.

"For we are not dealing here with questions of which the interest is abstract only . . . but with a matter which, take the world over, for every year that passes is life or death to myriads of men. . . .

"And let no one suppose that this is a matter in which he has no personal interest. This disease not seldom attacks the rich, though it thrives most among the poor. But by reason of our common humanity we are all, whether rich or poor, more nearly related here than we are apt to think. The members of the great human family are bound together by a thousand secret ties of whose existence the world in general little dreams. And he that was never yet connected with his poorer neighbour by deeds of charity or love, may one day find, when it is too late, that he is connected with him by a bond which may bring them both to a common grave." (William Budd, *Typhoid Fever*. London, 1873.)

TYPHOID FEVER.

CHAPTER I.

TYPHOID FEVER.

TYPHOID FEVER, or enteric fever, is an intestinal disease, caused by a microbe known as "Bacillus typhosus," or more commonly as "B. typhi," or "the typhoid bacillus." Through the multiplication of this germ within the body, with the consequent production of a poisonous substance, which, for want of a better understanding, may be termed typhotoxin, morbid conditions are produced in various parts which give rise to the characteristic symptoms of the disease. Ulcerations of the intestines and enlargements of the mesenteric glands and spleen are the most pronounced of these lesions; but being transported by the blood the bacilli often invade other organs of the body, — the kidneys, the liver, the lungs, the bone-marrow.

Symptoms. The symptoms of a typical case of typhoid fever are well defined, but so many exceptional or atypical cases occur, and the early symptoms are so often indistinct, that errors in diagnosis are not uncommon. The most characteristic symptoms are a gradually increasing and regularly fluctuating temperature, general prostration, diarrhea (or perhaps constipation), frontal headache, nose-bleed, dry cough, enlarged spleen, rose-rash over the abdomen and sometimes elsewhere, gaseous distension of the intestines, emaciation, and, in severe cases, intestinal hemorrhages, and delirium. These symptoms cover an average period of four or five weeks, but they may be preceded by a week or two of general malaise, and are followed by a rather long period of convalescence, during which relapses are not infrequent. Fatal cases usually terminate during the fourth or fifth week of the disease, or after a relapse.

Diagnosis of typhoid fever cannot often be made within four or five days after the onset, as many of the symptoms may be wanting in any particular case. The presence of the rose-rash or a positive bacteriological test of the blood are usually necessary to make the diagnosis certain.

A Typical Case. A typical case of typhoid fever is likely to give the following medical history:

Between the time when the typhoid bacillus enters the body and the time when the patient realizes that he is seriously ill, there is a so-called incubation period, or prodromal period, which usually lasts about two weeks, but which may vary from one week to three. During this time the health may be apparently unaffected, but more often the patient feels played out, loses appetite, and "aches all over." The true onset is generally accompanied by symptoms which compel the patient to take his bed and call his physician. There may be shivering, or perhaps a chill, headache, a coated tongue; perhaps nose-bleed or a bronchial cough; fever, restlessness and insomnia, muscular weariness, thirst, nausea; there may be either diarrhea or constipation. These symptoms continue during the first week, the temperature gradually rising to 103 or 104 degrees at night, with a corresponding increase in the morning temperature, which is lower than at night, the pulse also showing a slight elevation.

During the second week most of the symptoms become worse, but headache and nausea disappear. The temperature rises to 104 or 105 degrees, with morning remissions of one or two degrees; the pulse rises to 100 or 110 and becomes weaker. Prostration and apathy become great, the voice feeble, the tongue dry and brown. The bowel discharges are frequent and loose, pale yellowish brown in color, and more or less lumpy. About the eighth or tenth day rose-spots about one-eighth of an inch in diameter appear on the abdomen, coming and going in successive crops, lasting only a few days each, and disappearing altogether during the third week. Nervous tremors become conspicuous, and there may be some delirium.

During the third week the night temperatures continue high, but the morning remissions may be somewhat lower. The patient becomes emaciated, semi-conscious, and perhaps delirious. The stools may become tinged with blood, the urine lessened in amount. During this week, pulmonary complications are most likely to develop, — sometimes pneumonia.

During the fourth week night temperatures slowly fall to 102 or 101 degrees, while the morning temperatures begin to approach normal, even becoming sub-

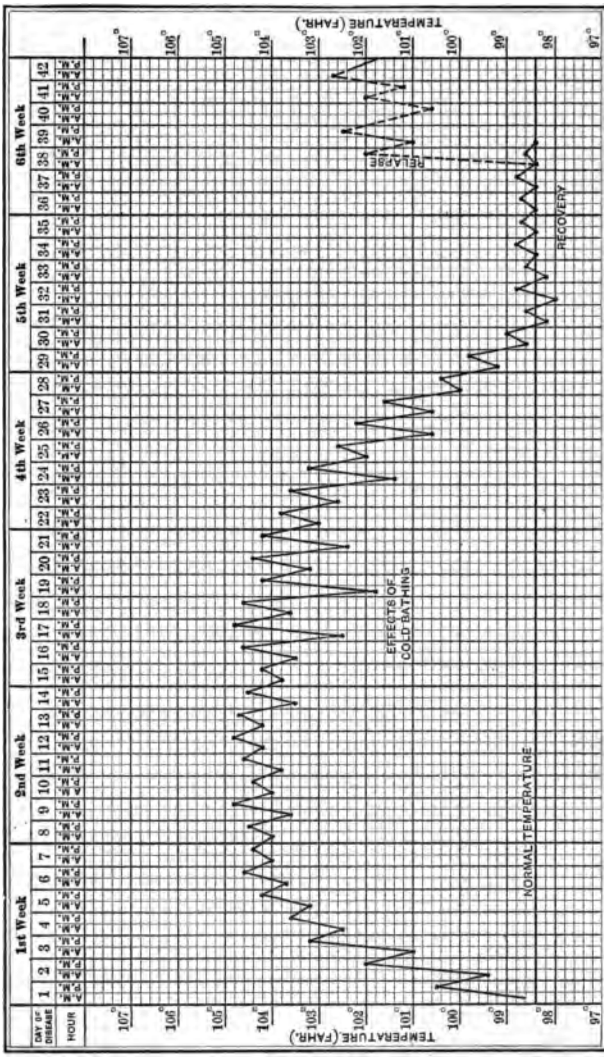


FIG. 1.

Diagram showing the Temperature History in a Typical Case of Typhoid Fever.

normal in some instances. With lower temperatures all the symptoms tend to improve, the pulse grows stronger, the mind becomes clear, the tongue becomes moist, and the patient begins to desire food.

The fever sometimes persists for a few weeks longer, but usually the fifth week begins the period of convalescence, which may last anywhere from two or three weeks to as many months, and if no complication sets in the patient recovers. Indiscretions in eating, in exercise, or exposure, however, may cause a dangerous relapse, during which there is a repetition of the original symptoms. The second attack is seldom as severe as the original one; but, on the other hand, the reserve strength of the patient is correspondingly less, so that relapses are always to be dreaded.

Treatment. Good nursing, proper diet and hygiene, and the free use of the cold bath, effect a cure in from 90 to 95 per cent of the cases. Medicinal treatment aimed directly at the disease counts for little, and thus far no antitoxin has been found to counteract the effect of the bacterial poison similar to those which have accomplished such marvelous results with diphtheria and tetanus. Medical treatment is devoted rather to assisting the various organs of the body to perform their normal functions under the unusual conditions, to prevent any overstrain on any weak organs, and to ward off, as well as possible, any unusual complications. Nature practically cures the disease, and both nursing and medical treatment are adjusted so as to give Nature as free a hand as possible in doing so.

Complications. It is said that not over a third of the deaths from typhoid fever are due directly to the effects of the disease, i.e., to the effects of the typhotoxin. Two-thirds of the deaths are due to the numerous complications, among which pneumonia and tuberculosis are prominent. This is a most important matter to sanitarians in connection with death certificates.

"Walking" Cases. Some cases are so mild that they are not recognized as typhoid fever at all. The patient, though not feeling well, remains up and goes about his usual pursuits. Ultimately he may recover without knowing he has had the disease, or he may suddenly become seriously ill. Such cases are called "walking" cases, and for obvious reasons they are especially dangerous to the public. Children, particularly, are liable to have mild attacks of typhoid fever which go unrecognized. It seems probable also that a person may harbor the typhoid bacillus without having the disease at all. Reference to the so-called "typhoid carriers" is given on a later page.

Details of the various symptoms, methods of treatment, studies of exceptional cases, complications and after-effects, are important matters to be considered from the standpoint of the patient and of the physician, but less so from that of the sanitarian, whose interest lies chiefly in those things which concern the transmission of the disease or which affect the vital statistics. So far as the disease itself is concerned the most important facts for him are those which throw light upon the probable date of the infection and the duration of any particular case.

Allied Diseases. There are several intestinal diseases closely allied to typhoid fever, milder in character, and not as definite, either in their pathology or bacteriology. That which is most like the typical disease is known as paratyphoid fever. This term has not yet come into common use among practicing physicians, and its systematic position is not well established. Many bacteriologists, however, recognize the paratyphoid bacillus as distinct from bacillus typhosus. Then there is a certain type of dysentery caused by the Shiga bacillus, — in fact there are several varieties of this bacillus.

These dysenteries are sometimes termed "infantile cholera," "winter cholera," "summer complaint," etc. Then there is, of course, the true Asiatic cholera, which is similar to typhoid fever in its modes of transmission.

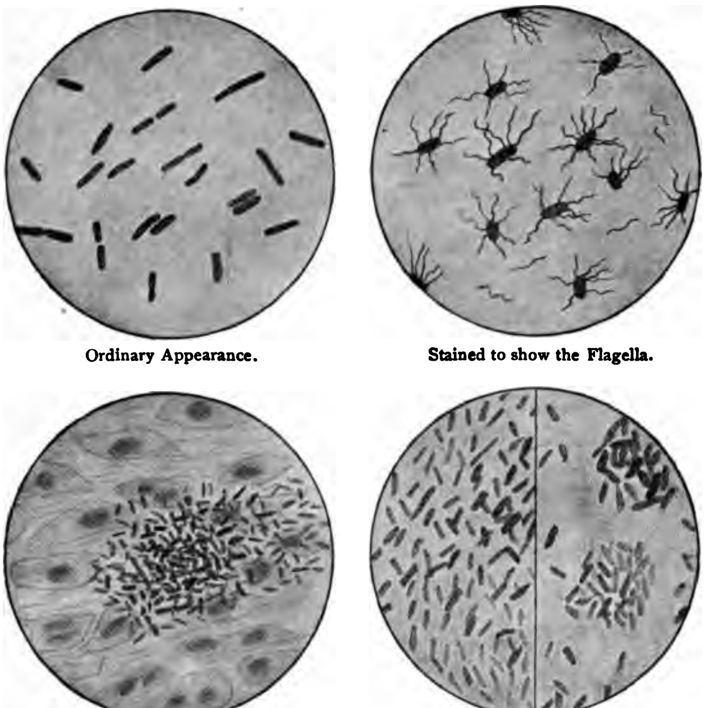
If this were a medical book it would be appropriate to discuss these allied diseases, but as the factors that influence their transmission are very largely the same as in the case of typhoid fever, and as the bacteriology of the diarrheal diseases is in an uncertain and controversial state, no further reference to them will be made.

CHAPTER II.

BACTERIOLOGY OF TYPHOID FEVER.

THE typhoid bacillus was discovered by Eberth in 1880, and soon afterward was isolated and studied in pure culture by Koch, Gaffky, and others. It has been known to science only a quarter of a century, yet in that time it has been the subject of research by hundreds of investigators working in many lands. A mere list of the titles of the papers which have been written about typhoid fever would fill a volume of considerable size. Yet with all this study we know but little about the inner structure of the organism, little about its physiology, and little about the conditions which affect its behavior inside, or its longevity outside the human body. The little that we do know, however, is of great practical importance, and, considering the difficulties involved, is most creditable to the new science of bacteriology.

The Typhoid Bacillus. The typhoid bacillus is a minute vegetable cell, cylindrical in shape, with rounded ends, one to four microns long (0.001 to 0.004 mm.), or, say, 10,000 to 25,000 to the inch, and perhaps a third as wide as it is long; with no characteristic interior structure, no indication of spores, but covered on the outside with numerous long, undulating flagella which give the cell powers of lively motion in liquid media. The germs multiply by fission, — that is, by cross splitting, — each cell becoming two, and each two, four,



Ordinary Appearance.

Stained to show the Flagella.

Growth of the Bacilli in the Spleen.

Appearance of the Bacilli in the Widal Test, before and after "clumping."

FIG. 2.

THE TYPHOID FEVER BACILLUS.

Magnified about 1,000 Diameters.

and so on. Under the microscope, cells may be often seen in the act of dividing, — some with an elongation, some with a slight constriction, and some appearing as two cells attached; occasionally chains of divided cells may be seen, looking like links of microscopic sausages, but moving with a serpentine motion. So minute that half a million would scarcely cover the head of a pin, they have enormous vital power, and they increase so rapidly in certain artificial culture media that in two or three days a hundred may become a billion, and form colonies, or masses, visible to the naked eye. It is more by the study of these mass cultures and by the effect which their growth produces on the culture media than by the study of the individual cells, that the germs are identified. Without entering into the details of bacteriological technique, suffice it to say that by the combined study of morphology, physiology, and cultural characteristics, the typhoid bacillus can be recognized in the laboratory, isolated in pure culture, and submitted to various tests as to virulence, and longevity in various environments.

Specific Cause of the Disease. The question is often asked, How do we know that the so-called typhoid bacillus is the specific cause of the disease? It must be admitted that the direct proof is not as complete as in the case of some infectious diseases, for the reason that the lower animals are not, so far as known, susceptible to the disease. Horses, dogs, cats, guinea pigs, rabbits, etc., do not have typhoid fever. This closes the door on a most important field of research. The proof, therefore, must be of necessity circumstantial in character, except as accident has resulted in the direct infection of human beings with pure cultures of the organisms isolated and cultivated from a previous case of typhoid. But, though largely circumstantial, the evidence is nevertheless of the very strongest kind.

The Eberth bacillus can be isolated from persons sick or who have been sick with typhoid fever, and from those persons only. It is present in the blood and is found in enormous numbers in the urine and feces of typhoid patients. Water infected with such discharges has repeatedly been found to cause the disease in others. Peculiar and intimate relations have been established between the blood serum of typhoid patients, or of those who have recently had the disease, and pure cultures of the Eberth bacilli. Such blood, when added to broth cultures of the bacilli, causes a cessation of motility and a clumping, or agglutination, of the organisms not produced by the blood of a person who has not had the disease. (Fig. 2.)

Although animals do not suffer from the disease of typhoid fever, laboratory experiments have demonstrated that cultures of highly virulent typhoid bacilli introduced into rabbits and guinea-pigs have produced some of the symptoms of the disease and have caused death. In these experiments the most pronounced pathological conditions have been in the region of the intestines, and in some cases the bacilli have been recovered from the affected parts. In general, however, animal experimentation has given negative rather than positive results. There are, however, a few cases on record where typhoid fever has been contracted by workers in the laboratory who accidentally became infected with cultures of the bacillus.

In spite of lack of direct experimental proof that the bacillus of Eberth is the specific inciting cause of typhoid fever, the circumstantial evidence is so strong that bacteriologists and sanitarians are satisfied that this bacillus is the true and only cause of the disease.

Portals of Entry. The typhoid bacillus enters the body through the mouth, by ways hereafter described, and passes through the stomach into the intestines. That the germ can enter the body through any other portal than the mouth and intestinal tract is doubtful, although some pathologists have claimed that in rare cases it enters through the lungs.

The gastric juice, because of its acid character, tends to destroy the bacillus, and this, no doubt, prevents many a case of the fever. There would seem to be some advantage, then, in drinking water, if its quality is suspicious, at the close of a meal rather than before or between meals. Typhoid bacilli taken into the stomach at a time when there is a vigorous secretion of the gastric juice probably stand less chance of reaching the intestines alive than if swallowed at times when the stomach is not performing its digestive functions.

Multiplication in the Body. Having arrived in the intestines the bacilli find conditions more favorable for growth, and especially so in the lower third of the small intestines, where the inflammation and ulceration are most conspicuous. Just what occurs is not known, but it is thought that they force their way through the enfeebled membranes, enter the lymph and blood-channels, and are swept on through them to the spleen and other parts of the body. Multiplying in the so-called Peyer's patches and the glands of the intestines, the bacilli produce the characteristic ulcers. They accumulate in the spleen in enormous numbers, giving rise to a characteristic congestion of that organ; they may also accumulate in the liver, the gall bladder, the kidneys, the bladder; they have been found even in the lungs, the meninges, the saliva, the rose-spots, the marrow of the bones, and, what is of great importance, the blood. It is even believed by some that gall stones are of typhoidal origin.

Recent studies have shown that the germs are present in the blood in practically all cases during the entire course of the disease, but they are especially evident during the early stages. In fact some pathologists go so far as to state that during the first week of the disease typhoid fever is a septicæmia. Coleman and Buxton, who have made a careful investigation of this subject, have given data showing that in over a thousand cases in which the blood was examined, 89 per cent were found to have the germ in the blood during the first week, 73 per cent during the second week, 60 per cent during the third, 38 per cent during the fourth, and 26 per cent after the fourth week. They found that the period during which the germ was present in the blood corresponded to the duration of the fever symptoms. The appearance of the germs in the blood marks the onset of the disease, while their disappearance from the blood marks the beginning of convalescence. Some think, however, that the bacilli do not multiply in the blood, but that on the contrary, they "overflow" from the spleen and other organs into the blood and there die and liberate the toxin against which the body reacts.

Just how the typhoid bacilli penetrate the tissues of the intestines and get into the lymphatic system is not well known. That many persons take the germs into their system without succumbing to the disease seems certain. That persons whose systems are run down or enfeebled from overwork or exposure take the disease easier than persons in robust health is also certain; but that persons in robust health do not contract the disease is far from being the case. A recent theory which has been accepted by some German pathologists is that the invasion of the intestinal walls by the typhoid bacillus is due to the presence of certain intestinal parasites, or worms, which penetrate the walls and thus allow the bacilli to enter. American pathologists have not as yet accepted this theory, and the weight of evidence appears to be against it. Another theory that is attracting the attention of pathologists is that much of the so-called summer typhoid is due to the occurrence of other intestinal disorders which act as exciting causes, rendering the intestines more susceptible to the invasion of the typhoid bacilli than at other times. Another theory is that improper diet, giving rise to a congestion of the liver, may reduce the secretion of bile and thus deprive the intestinal tract of a natural disinfectant which tends to prevent adventitious bacteria from causing trouble. Others believe that the white blood corpuscles act as carriers of the bacilli from the intestines into the lymphatic system. Still another idea is that a first infection predisposes a person to acquire the disease after a subsequent infection and that this "hypersensitiveness" has much to do with the incubation period of the disease, — the original attack rendering the blood susceptible to its greater infection when the bacteria "overflow" from the spleen.

These and similar theories have yet to be proved. They may be more or less true, and some of them certainly seem reasonable; but it is hardly necessary to resort to them, in view of the known ability of the tubercle bacillus to pass through the intestinal membranes, and of the demonstrated ability of the typhoid bacillus to pass through parchment and collodion membranes.

Typho-toxin. During their growth the typhoid bacilli are active in producing a specific toxin which is liberated in the blood, and it is the reaction of the body against this which, in great measure, is responsible for the well-known symptoms of the disease. Depressing the powers of vital resistance, various organs become affected, and bronchitis or pneumonia may become established, the heart action may be weakened, and the nervous system deranged. Typhoid fever is therefore a disease which operates partly by the direct influence of the bacteria, and partly by the indirect influence of the poison which they produce.

Natural Defenses of the Body. As a natural defensive reaction against further invasion of the typhoid bacilli, there is to be found in the blood-serum of typhoid patients a bacteriolytic substance which is inimical to the growth of the organism. The nature of this substance is still shrouded in mystery, just as is the nature of typho-toxin itself, but that it tends to destroy the typhoid bacilli seems certain; though whether it neutralizes the effect of the poison which they produce, is less certain. It, no doubt, plays an important part in checking the disease and in rendering patients immune from a second attack. Attempts have been made to take advantage of this "antibody" to effect both prevention and cure of the disease, but thus far with little or no success. It has proved very useful, however, in diagnosing cases of typhoid fever by means of the so-called Widal test, often referred to as the "blood test for typhoid fever."

Widal Test. If a drop of blood from a person who has, or who has recently had, typhoid fever be mixed with 30 drops of sterile distilled water, and a drop of this mixture added to a drop of a broth culture of typhoid bacilli, and examined under the microscope, it will be noticed that after a few minutes the bacilli, which at first are motile and are uniformly scattered over the field of view, gradually become motionless, and then aggregate themselves into compact masses. This is known as the phenomenon of agglutination, or "clumping." This will not happen with the blood of a person not ill with the disease, or one who has not recently had it; nor will it ordinarily happen during the first few days of the disease. Neither will it happen if the blood of a typhoid patient is mixed with a culture of some other organism.[1] A positive Widal test obtained on the blood of a suspected case — that is, one in which clumping is observed — is therefore practically conclusive evidence that the

[1] There are some exceptions to these general statements, but they do not militate against the main propositions.

disease is typhoid fever. Conversely, the blood-serum of a person known to have had typhoid fever, or of an animal which has been rendered immune to the effect of injected cultures of the organisms, may be used to establish the identity of an unknown culture of bacteria, although this test is less definite in its results than the other. Various modifications of the original Widal test are now practiced. Dead cultures are used instead of the living typhoid bacilli, and the precipitation of the clumped bacteria in mass is substituted for the microscopical examination, thus simplifying the test, though probably at the sacrifice of accuracy.

Blood Tests. Perhaps a better test than the Widal reaction is the direct examination of the blood for the presence of the typhoid bacillus. This is accomplished by drawing a small quantity of blood from the ear or from a vein at the bend of the elbow into an all-glass syringe, and putting from 1 to 3 cubic centimeters of it into a flask containing 20 cubic centimeters of sterile ox-bile culture medium, and, after cultivation, examining this for the presence of the typhoid bacillus according to the method described on page 322.

Modes of Exit. That the typhoid bacilli are present in the body of every patient has been firmly established. How do they leave the body? In what numbers? In what condition? How long do they persist? These and similar questions are of great importance in considering the spread of the disease.

As typhoid fever is very largely a disease of the intestines, the bacilli ought obviously to be found in the discharges of the bowels. Bacteriological studies have shown that they are so found. They are especially abundant during the earlier stages of the disease, but decrease in numbers as the patient convalesces. They are more numerous in diarrheal discharges than in the more solid lumps of fecal matter. How long they persist in the bowel discharges after the patient is well, is not known, and the period naturally varies greatly in different individuals. In most cases no danger is to be feared after the patient has recovered; but it is the part of wisdom to consider the stools as suspicious, and to maintain disinfection, for at least two weeks after apparent recovery. In the "typhoid carriers" the feces may be infected for months and even for years.

No reliable figures are to be obtained for the number of bacilli in the bowel discharges, but the numbers for a single evacuation may easily exceed one billion; and there is ample reason to believe that the bacilli leave the body in a living and virulent condition.

The presence of the bacilli in the kidneys and bladder of many patients naturally causes the urine to become infected. Until within a few years this was overlooked, and the disinfection of urine was not considered as of great importance. Although the urine is not infected in all cases, it is now considered that its disinfection is even more important than that of the feces. Whenever the urine is infected, the numbers of typhoid fever bacilli found in it are enormous. Sternberg cites a case where each cubic centimeter of a patient's urine contained 175,000,000 bacilli. This would amount to approximately 200,000,000,000 a day. Furthermore, the bacilli frequently persist in the urine for several weeks after convalescence and after the practice of disinfection is ordinarily discontinued. For these reasons urinary infection is more to be feared than fecal infection.

In some cases the bacilli are found in the mouth and throat. Consequently the saliva may contain them. This condition may be infrequent, but it is always liable to occur.

There is practically no danger to be feared from the quietly exhaled breath, as bacteria do not readily leave a moist surface; but coughing or sneezing may cause the expulsion of the bacilli into the atmosphere, with consequent dangers to persons in the room who may inhale them. The sputum of a typhoid patient is likewise a possible source of infection, especially in those cases where pneumonic symptoms are prominent.

The bacilli have been found in the perspiration; and although the danger from this source is probably quite remote, it is one that ought not to be overlooked.

Generally speaking, it may be said that it is chiefly in the urine and the bowel discharges that the typhoid bacilli leave the body of the patient, but in some cases they may leave by way of the nose and mouth, or by even the perspiration.

Typhoid Carriers. While it seems generally true that the body becomes quite free of typhoid bacilli within a comparatively short time after recovery, recent studies have shown that in a very small percentage of cases the germs may persist for months and even years. Such persons become "typhoid carriers." They may be in good health, and yet be a constant source of danger to others — all the more dangerous because unsuspected.

European observers found that about 3 per cent of 1782 cases examined by them became typhoid carriers, and a few cases of this kind are on record in this country. One of the best known is that of "Typhoid Mary," a cook in New York City, who, in good health, and changing from place to place, left a trail of at least twenty-eight typhoid cases in the houses where she had served, until the facts were finally found out. Bacteriological studies made by the health department showed that she was a "typhoid carrier." Typhoid fever bacilli were found in her feces. To prevent her from being a further menace to the community, the department of health placed her in a hospital and are endeavoring to effect a permanent cure.

There is reason to believe that typhoid carriers may develop from "walking cases" and even from those who are not cognizant of having had the disease. Such cases are probably quite rare, but they are especially dangerous, and no doubt account for some of the "sporadic" outbreaks, that is, for the sudden occurrence of the disease in places where it was never before known to occur and where there was no apparent cause.

CHAPTER III.

THE TYPHOID PATIENT AS A FOCUS OF INFECTION.

MODERN sanitary science declares that every case of typhoid fever is caused by an infection with bacilli derived from some previous case of typhoid fever. Sometimes there is direct contact between patient and victim; but more often the victim is unknown to the patient, and far removed in time and space. The modes of conveyance of the bacilli may not always be known, but the bacteriology of to-day insists that there must be some mode of conveyance, and that the disease cannot be produced by bad air, bad water, bad food, faulty plumbing, or by climatic conditions, however unfavorable, unless the typhoid bacillus is involved.

The Endless Chain. Sanitary science declares further that every case of typhoid fever is potentially a focus of infection; that virulent bacilli may and do leave the patient's body; and that unless proper precautions are taken, these bacilli may become scattered in various ways, and ultimately give rise to new cases.

In former days the spread of typhoid fever went on as an endless chain, like the mailing schemes in which one sends a begging letter to five persons, and each of these sends a similar letter to five other persons, and so on. To break this chain as near as possible to the original link is the aim of modern sanitary science. It is a task which cannot be accomplished single-handed; it requires the coöperation of the patient, the attending physician, the nurse, the members of the household of the patient, and the public health authorities. Each has a responsibility which cannot be shifted to others.

Barriers against Spread of the Disease. Every typhoid case should be surrounded, as it were, by a series of barriers, through which, in order to escape, the typhoid germs must pass. Should the germs pass the first line of inclosure, they should be held by the second; and should they pass the second, they should be retained by the third. If these barriers could be faithfully maintained the ravages of the disease would soon be checked; but through mischance or ignorance, or more often through negligence, some bacilli do escape through all the barriers and become scattered at large.

Vehicles of Infection. Through various agencies the vagrant germs are carried to their victims. Some of these agencies are well known; but there are, no doubt, others not yet brought to light.

Carriage by water is one of the most important modes of transmission, and the one which, by reason of the magnitude of its effects in large communities and the spectacular character of frequent epidemics, has most attracted the attention of the public. Transmission by flies from infectious matter in the privy to food in the kitchen, i.e., from improperly guarded fecal discharges to unscreened houses, is probably of common occurrence, especially in summer and in rural districts, and may be one of the chief causes of the summer and autumnal typhoid. It has come to be well recognized also that milk, oysters and other shell-fish, raw fruits and vegetables from gardens fertilized by human excrement or handled by persons sick of typhoid, may carry the bacilli.

Contagion. Nor must transmission by contact, that is, by contagion, be overlooked. A patient who sneezes into his nurse's face; a convalescent who handles a piece of cake or some dainty and passes it to another member of the family, or who shakes hands with a visiting friend, or who uses the "family towel," may unwittingly spread the disease. Typhoid fever is both contagious and infectious.

For the sake of clearness and emphasis, these various modes of transmission are expressed diagrammatically in the frontispiece, together with the barriers which should surround the patient, and certain lines of defense which should be established to protect other individuals from the typhoid bacilli at large.

First Barrier.

The first fight against the spread of typhoid bacilli must be made in the sick-room. It may be fairly assumed that the patient is ignorant of the nature of his disease until he calls the doctor, and the family physician is ordinarily the first to diagnose the case. The initial responsibility for preventing the scattering of the bacilli, therefore, rests with him.

Duty of the Physician. The first duty of the physician is, of course, towards his patient; but his second is towards the other members of the household, and his third to the community; and the physician who neglects the last two should be considered guilty of malpractice as truly as he who neglects the first. The conscientious physician acts in a dual capacity, — as medical adviser and as sanitary guardian *ex-officio.*

Modern medical treatment of typhoid fever does not aim directly at destroying the bacilli in the body, but rather towards the maintenance of normal functions in order that the body may protect itself. From the standpoint of the patient this is doubtless the proper policy; but there is good reason to believe that without injury to the patient, physicians can do much more than they ordinarily do to reduce the number of bacilli discharged from the body. Intestinal disinfectants have little or no value in controlling the disease, but disinfection of the bladder and the urinary tract by the use of urotropin and similar drugs is a pronounced success, and its practice ought to become more common in typhoid cases. With proper precautions the danger of spreading typhoid fever by infected urine could be largely eliminated. Disinfecting washes for the mouth might also be of some use, but in most cases the condition of the patient is such that they could not be used.

Although the physician can do much to prevent the typhoid bacilli from leaving the body of the patient, it cannot be expected that any treatment will be wholly effective. Disinfection of the discharges is therefore always necessary, and, all in all, it is the most important sanitary precaution to be taken.

Duty of the Nurse. Disinfection must usually be done by the nurse or attending member of the family, but it should be ordered by the physician according to regulations established by the board of health. The original responsibility is with the physician. As soon as it is even suspected that a case is one of typhoid fever, disinfection should be prescribed. If the physician assumes that the members of the household are ignorant of the subject, he will be right in nine cases out of ten. He ought therefore to give most explicit directions as to what disinfectants to use and how to use them. Too often the physician's directions are given in an indefinite and perfunctory manner, and are carried out in the same spirit. Suppose "chloride of lime is ordered": the well-meaning but inefficient attendant sprinkles a little of this substance around, keeps it up as long as the patient is in bed, and then everybody forgets about it. Suppose he "orders corrosive sublimate," and cautions against its poisonous character: the result is that the attendant is either too much scared to use it in a proper manner, or is so reckless that there is danger of poisoning the whole family. He may "order the bedding to be disinfected": and this may be done a few times; but if the laundress finds that the chemicals are rotting the clothes or turning them dark, as will doubtless happen, the practice is very likely to be given up.

Disinfection. People do not like the smell of chloride of lime or carbolic acid, and in consequence too little of these chemicals is used, and the period of contact with the matter being disinfected is insufficient. In some places the chemicals recommended by physicians cannot be easily obtained. The writer recently investigated an epidemic in a town where neither chloride of lime, formaldehyde, or even corrosive sublimate could be obtained, even though the town had a drug-store. The question of expense also enters into the problem in some cases.

The result of this is that in the majority of typhoid cases which occur among the poorer classes, disinfection as now conducted by the "doctor's orders" is a mere farce, while among the more intelligent people it is often insufficient. Few indeed are the physicians who closely follow up their first instructions and personally see that they are carried out.

Nor ought they to be required to do so outside of the house. The disinfection and disposal of typhoid excreta is a matter of public concern, and should be supervised by the local board of health, just as much as rooms in which diphtheria and scarlet fever cases have been confined are disinfected. It cannot be expected that the actual work be done by a public health agent, as it is something which requires attention several times a day; but the board of health should furnish the chemicals, and see that they are used in a proper manner. In this matter physicians and the board of health should act in harmony. The board of health should prescribe the method to be used, and the physician should act as its agent in instructing the family of the patient as to the necessity of disinfection and as to the modes of procedure.

Report to Board of Health. If the responsibility for the disposal of infectious matter is to rest with the public authorities, they must be promptly informed as to the occurrence of the disease. In many states and in most cities the sanitary regulations require physicians to report cases of typhoid fever as they occur; but there is an almost universal carelessness among physicians in reporting cases, which is most discreditable to the profession, as it shows not only a lack of appreciation of the value of public sanitation, but an utter disregard for law. Study of statistics shows that very seldom are half the urban cases of typhoid fever reported to the board of health, while very often not one case in a dozen is turned in. Health officers who are responsible for the enforcement of the registration laws should be far more strict, and should not hesitate to exact full penalty from those physicians who fail to do their duty. The existence of an epidemic in a community is frequently not recognized until delayed reports accumulate in the office of the board of health, or until local gossip or the local press has called attention to it. Many days of valuable time which might have been used in searching for the cause of the disease, or in inaugurating a system of prophylactic measures, are thus lost, and it is no exaggeration to state that many lives have been needlessly lost because of the failure of physicians to report their cases promptly.

One reason for greater slowness in the reporting of typhoid fever cases than those of other diseases is the uncertain character of the disease in the early stages and the lack of well-defined symptoms. Some allowance must be made for this; but if suspected cases were reported, the authorities could often be of assistance to the doctor by making blood tests and analyses of fecal matter to confirm or disprove the diagnosis.

There are three things, therefore, which the physician can do to prevent the spread of typhoid bacilli: first, to adopt such measures with the patient as to reduce as far as possible the number of bacilli which leave the body; second, to order the disinfection of the feces, the urine, the sputum, the bedding, etc., according to the requirements of the board of health; and third, to report the case, as soon as suspected, to the board of health, in order that the public authorities may supply the needed disinfectants and superintend the disposal of infectious matter. This work, for which the physician is responsible, constitutes the first barrier against the spread of the disease.

Second Barrier.

Duty of the Household. If the walls of the sick-room mark the boundaries of the first barrier, the second line of inclosure is that which surrounds the premises in which the patient dwells. Some typhoid bacilli are sure to pass out of the sick-room, and upon the nurse and attending members of the family devolves the real task of extermination and control. The need of this task will be understood from what has been said regarding the exit of the typhoid germs from the body of the patient, and the various modes of conveyance of these germs to new victims; but for the sake of emphasis they may be listed as follows:

1. Disinfection of fecal matter.
2. Disinfection of urine.
3. Disinfection of sputum and vomited matter.
4. Disinfection of water used in bathing the patient.

5. Disinfection of bedding, clothing, towels, napkins, handkerchiefs, sponges, used about the patient.
6. Disinfection of knives, forks, spoons, cups, etc., used by the patient.
7. Disinfection of the hands of the attendants.
8. Proper disposal of feces, urine, etc., by burial in the ground, or in water-closet or privy, as occasion demands.
9. Disinfection of water-closet or privy seats, and privy vaults and cesspools.
10. Screening of privy vaults to prevent access of flies.

They might be summed up, however, in two words, — disinfection and cleanliness.

Disinfectants. The disinfection of infectious matter from typhoid patients is not at all difficult. The typhoid bacilli do not form spores and are easily killed. The chemicals required are not expensive, and may be easily and safely manipulated. It is necessary, however, to use the disinfectants in large enough quantities, to thoroughly mix them with the discharges, and to give them *time enough* to act.

Many different disinfectants have been recommended, — chloride of lime, corrosive sublimate, carbolic acid, formaldehyde, copperas, blue vitriol, and others, — and all of these have certain special advantages in particular cases; but all in all, for common practical use, there is no better substance for the disinfection of fecal matter, urine, or sputa, or for use in privy vaults or cesspools, than slaked lime freely used. It has the important advantage of cheapness and availability; it is without odor, and is such a well-known substance that no one fears its use. It is conspicuously white, so that its use is evident to the inspector. Being cheap, it is naturally used in large quantities, and this insures a more intimate contact with the infected matter. The other disinfectants named are perhaps more active chemical agents than lime, and smaller amounts may be used; but chloride of lime and carbolic acid and formaldehyde all have odors which people dislike, while corrosive sublimate is a powerful poison and has to be used with caution. For hospitals and for cases where trained nurses are employed, corrosive sublimate and carbolic acid are perhaps the most serviceable. So, too, for the cramped quarters of city apartments. But for use in isolated country houses, and among the more ignorant class of people, common lime is preferable.

In disinfecting the typhoid discharges, especial attention should be given to the feces in the earlier stages of the disease, and to the urine in the later stages. Even after convalescence the urine should be disinfected for several weeks, or until a bacteriological examination has shown it to be unnecessary.

Bedding and clothing soiled by the patient should be soaked for several hours in a solution of carbolic acid or bichloride of mercury, and afterwards washed in boiling water. Handkerchiefs should be similarly treated, though, preferably, inexpensive cloths should be used for the sputa and afterwards burned. Spoons, cups, and other articles handled by the patient should be soaked in disinfectants before washing; and, as a further precaution, certain particular articles of this character should be set apart for the exclusive use of the patient.

Detailed instructions for the use of disinfectants are given on page 287.

Disposal of Fecal Matter. After two or three hours of contact with the disinfectants, the fecal matter, urine, etc., must be disposed of. While standing they should be carefully covered to protect them from flies. In houses provided with water-closets connected with the public sewers this is the natural and proper place of disposal, but in country places burial in the earth is preferable to disposal in a privy or cesspool. The earth for a foot or more down from the surface is teeming with bacteria and other forms of life, and when typhoid bacilli are buried in the ground they are soon destroyed. Care should be taken in the selection of a spot. It should not be near a well, nor in a garden where garden truck is raised. A convenient mode of burial is to dig a trench a foot deep, throwing the earth to one side and covering each deposit as soon as it has been placed in the ground. The urine, as well as the solid matter, should be poured into the trench and covered, and not poured on the top of the ground, as is too often done.

During the winter, when the ground is frozen or covered with snow, burial in the earth should not be attempted. It is better to use the privy or cesspool, and thoroughly disinfect it and clean it as soon as there is opportunity. Above all things, the discharges should not be put on top of frozen ground. This procedure has been the cause of some of the most severe epidemics that have ever occurred in this country.

If the discharges are thrown into a privy vault, this should be thoroughly disinfected with lime, and each new deposit should be immediately covered with lime. The back of the vault and the windows and ventilators of the privy house should be carefully protected from flies by means of screens; all cracks should be covered with paper pasted over them; a self-closing seat cover should be used, and a spring should be placed on the door to render it self-closing.

If the discharges are thrown into a cesspool, or into a water-closet which connects with one, it should be disinfected most thoroughly, and great care should be taken with the material removed at subsequent cleanings. In fact, to guard against future danger the cesspool should be emptied and disinfected as soon as the infected sewage has ceased to flow into it.

Cleanliness. Above all things, scrupulous cleanliness is required on the part of the attendants, both in the interest of self-protection and that of preventing the spread of the disease to other members of the family. This is especially necessary in the sick-room. A drop of urine or a speck of fecal matter no larger than a pin-head may contain hundreds of thousands of bacilli; hence care against the spattering of such matter is important. In caring for a patient, the hands of the nurse are very likely to come in contact with infectious matter. Washing and disinfecting the hands after leaving the bedside are therefore demanded. A careless attendant going from the bedside to the kitchen and there preparing the family meals may convey the disease to the whole household. Cases are on record where this has occurred.

Isolation. The isolation of the patient is important. He should have a room by himself, or at the very least a bed by himself. In crowded quarters this is often difficult of attainment. The author once saw a man sick with typhoid fever in a room occupied by fifteen others, there being four beds occupied by Hungarian laborers who worked in day and night shifts, and the woman who took care of the beds and tended the patient prepared the food for the sixteen men. In such a case the only recourse is to remove the patient to a hospital.

While isolation of the patient is desirable, a strict "quarantine," in the sense in which the word is generally used, is unnecessary.

The sick-room should be thoroughly screened to prevent flies from carrying about the infection.

Children. Children should not be permitted to run in and out of the sick-room, or to share with the patient the dainties which are so often furnished. Their inquisitiveness and their innocent desire to be of service to the sufferer often result most disastrously.

The convalescing patient must remember that he is liable to be a focus of infection for a number of weeks after he leaves his bed, and should take unusual care not to infect other members of the family.

The work of disinfection and the care exercised by the household of the typhoid patient thus constitute the second, and most important, barrier against the spread of the disease.

Third Barrier.

Duty of Public Authorities. The final responsibility for the prevention of the spread of typhoid fever rests with the public, acting through the board of health, or the health officer, or other properly constituted authority. This demands the exercise of various activities, such as, —

1. Consideration of reports of physicians.
2. Diagnostic tests.
3. Supervision of the disposal of infectious matter.
4. Distribution of disinfectants.
5. Purification of sewage.

Before the board of health can act in a case of typhoid fever, it must have a knowledge of the existence of the case, which should come to it from the physician. Stringent laws requiring doctors to report their cases *promptly* should be passed and rigidly enforced.

Many doctors hesitate to report cases for fear that their reputation may suffer through an occasional faulty diagnosis. If, however, the law required *suspected* cases of typhoid fever to be reported, there would be no such feeling; and if a second report should reverse the decision of the first, or if the blood test should give a negative result, no harm would be done. The failure to report a case of real typhoid fever works far greater damage than the report of a suspected case which proves to be something else.

System of Reporting. Everything should be done to make the work of reporting typhoid cases as easy and automatic as possible. Physicians are busy men, irregular in their hours, and often away from home for a large part of the day. Suitable postal card blanks, stamped and addressed, should be freely supplied to the doctors, and arrangements should also be made for report by telephone. The nature of the physician's report is referred to on page 218.

Blood Tests. The board of health, having received the report of a suspected case, should be prepared to verify the same. This involves the application of the Widal test to the blood of the patient, or some equivalent test, and requires the services of a bacteriologist and a laboratory equipment. Most of the large cities are now able to do this work; but in the case of small communities which cannot assume the entire expense, it should be done by the county or state, or conducted on some coöperative basis. Results of these tests would not only be of great assistance to the physician, but they would greatly strengthen the position of the board of health in the matter of disinfection. The board of health should also be prepared to make bacteriological examinations of the feces and urine of convalescing patients. These tests are coming to be regarded as quite as important as the Widal test.

Supervision over Disinfection. The board of health should maintain a general supervision over the disinfection of typhoid excreta, and should establish regulations and secure the coöperation of the physicians in having them carried out. It should provide all needed disinfectants and distribute them in proper receptacles, accompanied by simple but full directions for use. The gain to the community by this public distribution of disinfectants would more than justify its cost.

Sewage Disposal. Leaving the household we now come to the larger question of the disposal of the sewage and other wastes of the community. These are emphatically public matters, though they fall within the domain of the engineering departments of a city rather than that of the department of health as ordinarily constituted.

A number of years ago, a sewerage system was considered to be complete if it satisfactorily collected, without nuisance, the sewage from the houses and let it go somewhere, anywhere, into the harbor, into the lake, or into the river, according to situation, — out of sight, out of mind. Sewer gas was regarded as dangerous; the sewer liquid was regarded merely as a nuisance. Now this is reversed, and the liquid sewage, germ-laden and infected, is known to be the thing to be most feared. Sewage disposal is therefore now looked upon as quite as important as sewage collection. Recent years have seen some extraordinary developments in the art of sewage purification, and coming years are destined to see far greater advances.

There is a good deal of misconception about the subject of sewage disposal. Sanitary problems are not necessarily involved, although they usually are to some extent. In some places it may be merely a question of nuisance, — and it must be remembered that a stream which has bad odors and which is offensive to the sight will not cause typhoid fever, unless the typhoid germs are in the water, and unless the water gets into the mouth.

This is not the place to discuss the general subject of sewage disposal, but a few facts are worthy of notice at this point.

There are various methods of sewage purification, some of them of modern date, involving septic tanks, chemical precipitation basins, contact beds, sprinkling filters, etc. These and similar agencies are usually installed for the purpose of improving the chemical character of the sewage, and to prevent its subsequent decomposition, with attendant nuisances. If properly built and properly operated, and enlarged from time to time according to need, they do in a satisfactory manner the work for which they were designed; they even do more, — they accomplish a marked bacterial purification of the sewage. But their chief function is to destroy dead organic matter, not living organisms, — although living organisms are concerned in the process. They do not render sewage fit to drink; and if the effluent is turned into a stream used for drinking, some danger of contamination still remains. Such systems reduce the danger of contamination, but they do not wholly remove it. In this respect the old systems of purification by intermittent filtration and broad irrigation are more to be depended on, but even these processes are not complete.

There is a growing feeling among sanitarians that nothing less than a secondary filtration of a sewage effluent, carried out substantially on the lines of water purification, or a disinfection of the effluent by means of chemicals, is necessary in order to render sewage free from pathogenic bacteria.

Whether or not the sewage of a city or town should be purified to such a degree as to destroy pathogenic bacteria, is a question which must depend upon the local surroundings, and must be decided independently for each particular case. If the sewage of a city flows into a stream used in its lower reaches for purposes of public water-supply, that city is at least morally bound to keep infectious matter out of the river.

The courts are beginning to decide that where a city is supplied with public sewers the municipality is responsible for any damage occasioned by the pollution of a stream by this sewage. Although thus far this decision has been applied only to cases of nuisance, in time it may be extended to cover cases of infection.

Disposal of Fecal Wastes on Boats and Trains. The disposal of water-closet wastes on steamboats and trains is something that demands serious consideration. The pollution of the water of lakes from steamboats passing near a water-works intake, and the scattering of fecal matter along the road-bed of a railroad, passing over some water-shed used for public supply, are likely to bring disaster. Although the chance of danger may be small in comparison with other causes of typhoid fever, yet the practice is unsanitary and disgusting. In some places trains passing through territory tributary to a water-works reservoir are compelled to have their closet doors locked. While this prevents contamination of the road-bed, the continual damage to the health and comfort of passengers by reason of deprivation of toilet privileges might easily be a more serious matter than the chance of damage done to some water-supply.

The practice is only to be tolerated as a temporary expedient. What is needed is some form of receptacle to be used on the train that will hold the urine and excreta until they can be safely removed at the end of the journey or at some intermediate point. There is certainly ingenuity enough among our railroad men to provide some device that will do this without nuisance to the passengers. The present toilet-room arrangement in the ordinary day coaches is usually an abomination.

Care of Toilet-Rooms. The lack of care of the toilet-rooms in most railroad stations is another wrong that needs righting. Used promiscuously by the careless, the ignorant, the sick, they are seldom cleaned, and rarely or never disinfected, while flies swarm through the windows, and vermin crawl on the floor. This is more likely to be the case in small way stations than in the terminal stations of large cities. What is true of railroad toilet-rooms is true to some extent of factories, schoolhouses, and public buildings.

All such toilet-rooms open to the public or used by large numbers of people should be under regular inspection by the health authorities, and occasional disinfection should be required by law.

Flies. The public authorities can help to prevent the spread of typhoid fever, as well as other diseases, by bringing about conditions of general cleanliness. "Dirt breeds disease." One cannot tell how far this trite saying extends, but every year bears new testimony to its truth. Flies, which may be often the means of transmitting typhoid fever germs, develop from eggs, and these eggs are very commonly laid in manure piles. Dr. L. O. Howard, the entomologist of the United States Department of Agriculture, states that the house-fly prefers horse-manure as a breeding-place, although it may breed in other fecal matter. Dangers may arise from the location of stables in crowded communities, and hence strict rules should be made in regard to the care and storage of manure. The disposal of garbage is also an important matter, as the common little fruit-fly is likely to be the means of conveying the typhoid bacillus.

The war on flies has scarcely begun; when it does begin, it will involve many reforms. Among these will be cleaner streets, and especially the prompt removal of horse-manure, better care of stables, better care of vacant lots, better care of wharves and markets, better protection of garbage pails, and a general attempt to eliminate the breeding-places of flies and insects. More attention will be given to screening public buildings, schoolhouses, hotels, restaurants, etc.

In these various ways the public authorities, representing the whole people, can establish a final and exceedingly important barrier against the spread of the typhoid bacillus.

CHAPTER IV.

THE TYPHOID BACILLUS AT LARGE.

It is easier to keep the pig from getting out of the pen than it is to catch him when he is out. It is easier to keep the sparks from scattering from the fireplace than it is to put out the conflagration that the sparks have kindled. So, also, it is easier to prevent the germs of typhoid fever from leaving the sick-room than it is to avoid them, or to discover and destroy them, after they are out of bounds. But, in spite of all precautions, sparks will sometimes scatter, pigs will get loose, and typhoid germs will escape through all the barriers. Our next study, therefore, must be the typhoid bacillus at large.

The Typhoid Bacillus Outside the Body. Bacillus typhi is essentially a parasitic organism. A common habitat, and apparently its favorite one, is the human body. There it may find for a time conditions favorable for growth. Unfortunately, however, it does not die as soon as it leaves the body, but, unless destroyed, maintains a vagabond existence in various places and for various lengths of time, ultimately perishing of exposure or starving to death, or, with better luck, finding once more a temporary home in the intestines of a new human host. The whole story of the saprophytic existence of the typhoid bacillus — that is, its life outside of the body — is far from being known, but much has been learned during the last ten or fifteen years regarding its longevity in different media, and the influence upon it of heat and cold, dryness, pressure, oxygen, food-supply, poisons, etc. How long will the typhoid fever bacillus live in water? How long in ice? How long in milk? In the soil? In oysters? How does its vitality when it leaves the body affect longevity? And how does environment affect its virulence? These are some of the questions which the sanitarian needs to have answered, and they are among the most difficult and complicated problems which the bacteriologist is called upon to solve. Little wonder that the experiments thus far made have not been in entire accord and that experts have sometimes disagreed on these important matters.

Requirements for Growth. The three principal requirements for bacterial growth are food, moisture, and warmth, but many other factors affect longevity. Some of these are of a general character, but most of them may be most conveniently discussed under the heads of water, milk, ice, and the soil.

Moisture. Moisture is essential to the growth of the typhoid bacillus, as it is to all vegetable life. Drying is for this organism more fatal than it is to many forms, and even a short period of desiccation results in death. Some bacteria, as, for instance, the bacillus of tetanus, form spores which are provided with a firm cell-wall that enables them to withstand drying. They are able to maintain a latent existence, as a seed does, and then, after a period of inactivity, when the conditions become favorable, germinate and multiply once more. It is for this reason that the dried sputum of a consumptive is to be feared, and it is for this reason chiefly that dust is dangerous. But, so far as is now known, the typhoid bacillus does not form spores, and there is little or no danger to be feared from dust or from the air, unless this dust or this air has had opportunity for recent infection. The danger from dust should not be wholly ignored, for, although no spores of the typhoid germ have ever been discovered, experiments have indicated that among the many individual cells of a culture, a few often seem to have powers of resistance against an unfavorable environment far above the general average. Furthermore, a particle of dust dried only on the outside may harbor living germs within. Generally speaking, however, drying kills the typhoid bacillus.

Typhoid germs do not readily leave a moist surface. Sticky by nature, they adhere until desiccation loosens their dead cells. For this reason sewer air is not to be looked upon as a direct means of infection. Experiments have shown that the air of the Paris sewers contains fewer bacteria than the air in the streets above them. Laborers who work in sewers are not more afflicted with air-borne infectious diseases than other laborers. The exhaled breath is practically sterile. One may blow for some time through a tube into a sterile culture medium without contaminating it. But the constant breathing of sewer air, or "sewer gas" as it is often called, may have a depressing effect on the system, and render one less liable to resist infection. The exhaled breath during coughing and sneezing may contain a spray of saliva that may be dangerous.

Sunlight. Sunlight is a strong germicide. It has been often shown by laboratory experiments that cultures of typhoid bacilli and other bacteria exposed to the direct rays of the sun in a window are quickly killed or their numbers greatly reduced. The solar energy is a powerful aid to desiccation in rendering dust innocuous. "Letting in the sunlight" is not merely a figure of speech, it is one of the most powerful and beneficial of sanitary measures.

It is a common belief that sunlight exerts a potent influence in the purification of water in lakes and streams. To a certain extent this is true, but its effect is not as great as one might naturally expect, and often it is *nil.* The energy of the sun's rays penetrating a body of water is so rapidly absorbed in the upper strata that even at a few feet below the surface it has only a very small fraction of its value at the surface. This is the case in clear, colorless water: in waters which are muddy the absorption of light is even greater, and the sterilizing effect does not extend more than an inch or so below the surface. Many interesting experiments have been made to determine the intensity of the energy of the sun's rays as they pass downward into bodies of water. Photographic plates have been exposed at different depths; the decolorization of water has been studied; and sealed bottles of water containing known numbers of bacteria have been kept at different depths for equal intervals of time and the numbers of bacteria remaining ascertained. All of these experiments indicate that whatever sterilizing influence is possessed by the sun's rays is confined to a very thin layer, and that the more turbid or discolored a water is, the thinner is the stratum affected.

Temperature. The temperature relations of the typhoid bacillus are very important. The most favorable temperature for its development is probably that of the human body, namely, about 98.6 degrees F., or 37 degrees C. At much higher temperatures, and at much lower temperatures, according to laboratory experiments, growth in culture media is less rapid. Above 50 degrees C. (122 degrees F.) no growth occurs, while at the pasteurizing temperature (60 to 65 degrees C., or 140 to 160 degrees F.) practically all germs are killed even with an exposure of a few minutes. Boiling is, of course, *a fortiori* fatal. Milk pasteurized for ten or twenty minutes, or water brought to the boiling-point, may be therefore considered as practically safe from typhoid infection.

Typhoid bacilli grow luxuriantly in laboratory culture media at room temperature (20 degrees C., or 68 degrees F.). At lower temperatures their growth is checked, but is not entirely stopped even near the freezing-point. Freezing does not necessarily destroy bacterial life, though it has an important influence on longevity, as elsewhere mentioned.

Food. Like other bacteria, the typhoid bacillus requires a food-supply of organic and mineral matter, but the exact nature of its requirements both as to quantity and quality has never been determined. It is known, however, that so small an amount as one part of organic matter in a million parts of distilled water will materially prolong its existence. This amount of organic matter would be obtained by putting about one drop of milk in a gallon of water.

The Longevity of the Typhoid Bacillus in Water.

The typhoid bacillus does not multiply in ordinary drinking-water, even though the water be polluted. On the contrary, natural water is an unfavorable medium, and from the time when the germs enter a stream or a lake or a well or the salt water of the ocean, there is a constant dying off of the bacilli. The weaker cells die first, and there is generally a rapid initial reduction in numbers, due perhaps to the effect of plasmolysis, that is, to osmosis. Later the decrease is less rapid, but continues until all but a few bacilli have disappeared: ultimately all the cells die. This is the present conception of sanitarians, reached after a great amount of experimentation and the study of many epidemics.

Decrease of Typhoid Bacilli in Water. The rate at which the bacilli decrease in water varies very greatly, as might be naturally expected. Laboratory experiments are far from being in perfect agreement on this point. In some of the experiments almost all the bacilli have disappeared at the end of three to five days; in others ten per cent have lingered for a month. In very cold water the mortality is rather more rapid than in waters at summer temperature; in waters which are well oxygenated it is less rapid than in stagnant waters deficient in oxgyen; in waters rich in organic matter the longevity is greater than in distilled water, but in nature this is more than offset by the antagonistic influence of the more common water bacteria and of other organisms higher in the scale of life.

If, for the purpose of illustration, one wished to use definite figures to show the rate of decrease of typhoid fever bacilli in ordinary drinking-water under ordinary conditions, it might be said that after a week the water may contain 30 per cent of the number added, after two weeks 10 per cent, after three weeks 3 per cent, and after a month or six weeks 1 per cent or less. A fairer method of presentation, however, and one which gives latitude for different conditions, is shown by the following diagram, in which the curve illustrating the percentage decrease in number would fall somewhere within the shaded area. Time is evidently a most important element. Age does as much for water as it does for wine.

The Resistant Minority. It will be noticed that the curve in Fig. 3 does not fall quite to the zero line; in other words, the bacilli do not wholly disappear within the time indicated. This brings up a very interesting point, the importance of which is gradually impressing itself on the minds of bacteriologists. In almost all of the recent experiments which have been made to determine the longevity of typhoid bacilli exposed to unfavorable influences, such as heat, cold, freezing, or the action of various disinfectants, it has been noticed that a few individual cells seem to have greater powers of resistance than the general mass of cells in the culture. For example, occasionally bacilli may be found alive in milk

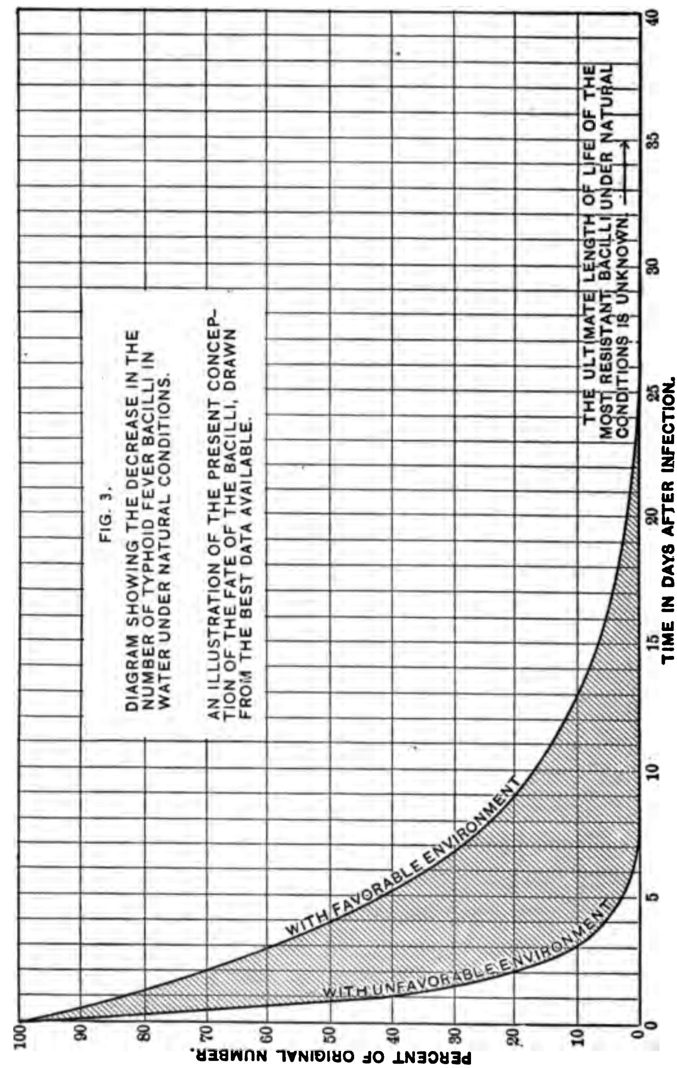


FIG. 3.

DIAGRAM SHOWING THE DECREASE IN THE NUMBER OF TYPHOID FEVER BACILLI IN WATER UNDER NATURAL CONDITIONS.

AN ILLUSTRATION OF THE PRESENT CONCEPTION OF THE FATE OF THE BACILLI, DRAWN FROM THE BEST DATA AVAILABLE.

after heating, or in ice after freezing, or in water to which a disinfectant has been added: and whereas, in experiments with drinking-water, most of the bacilli disappear in a fortnight or a month, a few hardy individuals may persist for a much longer period, — just how long nobody knows. Typhoid bacilli are not supposed to form spores, and what makes certain cells more hardy than their neighbors has never been discovered; in fact, little attempt has been made to solve the problem. But there are those who believe that many of the unexplained occurrences of typhoid fever might be made clear if we had a better understanding of the longevity of these resistant cells.

In considering the curve shown above, where 99 per cent of the bacteria disappear in a month or so, there is danger of focusing the attention on the 99 per cent removed, and forgetting the 1 per cent remaining. It must be remembered that a single discharge of the bowels of a typhoid patient may contain one billion typhoid bacilli, — perhaps more at times, — and that 1 per cent of one billion is ten million, — a number of bacilli large enough to do immense damage.

It must be remembered also that the conditions under which laboratory experiments are necessarily made cannot perfectly imitate the conditions of nature. It does not do to rely upon them too implicitly. On the other hand, the study of the bacilli in nature is attended with so many difficulties that results from such observations also have to be received with caution. Taking them at their face value, however, they show a greater longevity of the typhoid bacillus in water than would be inferred from the experiments made in small receptacles in the laboratory.

Some German investigators once isolated an organism which they believed was the typhoid bacillus from well water several weeks after infection, and one observer isolated the germ from the dead end of a distribution system five months after the probable date of infection. Hoffman, experimenting with an aquarium in which were various water plants, fish, snails, and many protozoa, and which was exposed to sunlight a few hours each day, recovered the typhoid bacillus from the water after thirty-six days, and from the mud at the bottom after two months.

Instead of casting aside such observations as of no value, it is worth while to see if they may not be explained by the long life of the resistant minority. While test-tube studies are tending to show a short life of the typhoid bacillus in water, observations in nature seem to indicate that some of the bacilli may remain alive and virulent for many weeks and months.

Longevity of the Typhoid Bacillus in Sewage.

The early experiments showed that the typhoid bacillus had a greater longevity in sterilized water than in water which had not been sterilized. Competition with other bacteria was apparently not favorable to a long life; but whether it was that these other bacteria robbed the organism of its food, or produced substances inimical to its growth, was not made clear. The difficulties of experimentation were great, and the identification of a few cells of B. typhi among thousands of ordinary saprophytic bacteria was so difficult that the negative results obtained from the unsterilized water have not been taken by sanitarians at their face value.

Decrease of Typhoid Bacilli in Sewage. But recent experiments made with greater care have apparently corroborated the early findings, and it is now becoming recognized that the typhoid bacillus has a shorter life in sewage, which teems with bacterial life, than in ordinary drinking-water. By putting the bacilli into a sterile liquid in parchment and collodion sacs, and suspending these in waters of different degrees of pollution, Jordan, Russel, and Zeit, working in the interest of the Chicago Drainage Canal, attempted to simulate natural conditions and at the same time to avoid the old difficulty of trying to find a needle in a haymow. It was thought that the porous membrane would permit the chemical substances dissolved in the sewage and the products of bacterial growth to pass into the sacs, while the bacteria themselves would pass neither one way nor the other. Examining the bacterial contents of the sacs from time to time, it was found that the typhoid bacilli lived longest in the purest water. In the highly polluted water of the Chicago Drainage Canal, they apparently disappeared in from one to three days, while in the water of Lake Michigan they lived from four to eight days. These experiments have attracted much attention, but later researches have somewhat discredited the technique employed, and the figures given ought not to be taken too literally. Notwithstanding their possible errors, they serve well to illustrate the general fact that the typhoid fever bacillus does not live as long in sewage as in pure water.

There are a number of reasons why this is so. Sewage is usually devoid of oxgyen, or nearly so, and experiments have shown that oxygen is necessary for longevity. More important, however, are the antagonistic influences exerted by the various saprophytic bacteria which are present in sewage in such enormous numbers.

Fate of Typhoid Bacilli in Cesspools. If the conclusions of these experiments could be fully trusted, typhoid-infected sewage that has remained for several weeks in a cesspool might be considered as innocuous, septic sewage might be less feared than fresh sewage, and sewage sludge might be safely used on gardens. In this matter, however, one ought not to lose sight of the "resistant minority." The danger that some bacilli may remain alive in sewage, whether in a septic tank or in a cesspool, always threatens, and the only safe way to deal with sewage is to assume that it is always potentially infective. Furthermore, there are the records of old experiments in which typhoid bacilli have been found to live months and even years in fecal matter, and in spite of all their shortcomings, these experiments cannot be safely ignored.

Efficiency of Sewage Purification. The fate of the typhoid bacillus in sewage purification works has been much discussed by engineers. Sedimentation of sewage in tanks generally removes two-thirds of all of the bacteria in the raw sewage, chemical precipitation may remove about 80 per cent, contact beds and sprinkling filters from 80 to 95 per cent, and intermittent filtration through sand from 95 to 99 per cent. It may be fairly assumed that any typhoid bacilli present in the sewage will be removed in amounts which are at least equal to these, and which, by reason of the antagonism of the sewage bacteria, may be even greater. Most sewage purification works are not intended to produce an effluent which is safe to drink, but rather one which is unobjectionable from the standpoint of appearance and odor. Sewage effluents, therefore, are liable to retain a portion of any pathogenic bacteria present in the raw sewage, and are, accordingly, dangerous. It is only by some subsequent treatment, such as disinfection by chemicals, or purification along the lines of water filtration, that such effluents can be rendered innocuous. To render sewage harmless, is by no means impossible of attainment, but it demands purification works of a high order of efficiency, which necessarily involve considerable expense and great care in operation.

The Self-Purification of Streams.

Intimately involved in the question of the longevity of the typhoid fever bacillus in water and sewage, is the old familiar theory of the self-purification of streams. Part truth and part error, the theory that "running water purifies itself" has lived through several generations, and still has a strong hold on the public mind. As its misapplication may do much harm, it deserves more than a passing notice.

Of a pitcher held under a faucet, it may be truly said that it is filling, yet it may be taken away without its being full. And with equal accuracy it may be said of a stream that it is purifying itself, while at the same time there may be no point in its course where its waters have reached what may be fairly termed a state of purity.

Streams do indeed tend to become better in quality as they flow — but what is the nature of the betterment, and what is its extent? All depends upon the answers to these questions. There are a good many factors involved in the problem. The most important, so far as they affect the bacterial contents, are (1) dilution, (2) sedimentation and scour, (3) longevity of pathogenic bacteria, (4) sunlight, (5) aëration, (6) antagonism of other organisms.

Effect of Dilution. By dilution is meant the attenuation of the substances dissolved in water, or the dispersion of bacteria and other suspended matter through greater volumes, due to accessions of clearer and purer water than that in the stream. Streams grow in size as they flow, and the scattering of the bacteria through larger masses reduces the danger from drinking the water, even though no real purifying agency is at work. In a practical sense, therefore, dilution is a sort of purification; but it is incomplete, — it merely minimizes the danger without removing it.

Sedimentation. In most streams there are places where the current is slack enough to allow some of the bacteria to settle; while in the long reaches through meadows and swamps, in the ponds behind mill-dams, and in quiet pools and eddies, a river tends to drop its burden of suspended matter, and the flowing water becomes purified to the extent of these depositions. This is a true purification, as many of the bacteria may die after subsidence; but it is only a partial one. The periods of low flow, when velocities are reduced to the point where sedimentation occurs, are interrupted by floods which scour out the deposits and carry them farther down stream, thus for a time decreasing the purity of the water. Sedimentation and scour are complementary forces; one purifies, the other pollutes; but the balance of their combined effect on the water of the stream is a purifying one.

Time the Greatest Factor. The natural longevity of the typhoid bacillus in water has already been mentioned, as well as the effect of sunlight and the antagonistic influences of other organisms. It has been said above that to a great extent longevity is a function of time, and that the danger of using infected water gradually lessens as the period between infection and use increases. In the self-purification of streams, therefore, it is not a question of the distance that a river flows, but rather of the time it takes for the water to flow from one place to another that determines the extent of purification. A rapidly flowing mountain stream, if infected, is likely to carry its infection quicker and farther than a slow and tortuous stream flowing through a plain.

Aëration and Oxidation. Aëration counts for much in the self-purification of many streams, but its effect on the bacterial contents of water is slight. The exposure of water to the air as it falls over a dam or ripples down a rocky bed tends to eliminate any odoriferous gases that may be dissolved, and to restore any oxygen that may have been used up by polluting substances. Aëration may improve the taste and odor of water, and help to oxidize the organic matter present, but it does not destroy pathogenic bacteria in appreciable numbers; in fact, experiments have shown that typhoid bacilli live longer in water which contains oxygen than in water which does not. The vigorous agitation that water gets in a rapid current may shake the life out of some weak cells, but its influence as an agency of purification is insignificant. The author once fastened a bottle of water containing typhoid bacilli to the piston-rod of an engine, and thus it was shaken vigorously for many hours with no important reduction in the number of germs.

Present Status of Theory of Self-Purification. The theory of the self-purification of streams has had many ups and downs. Its present standing among sanitarians may be summed up as follows: Polluted rivers under natural conditions tend to become pure. The improvement is often conspicuous to the eye. The wholesomeness of the water also tends to improve, but not to as great an extent as its improvement in appearance would indicate. Save in a few rare instances where exceptional conditions prevail, the natural agencies of purification cannot be depended upon to render a contaminated river water safe for drinking. These rare instances are where the contamination is originally very small as compared with the volume of the stream, or where the time interval is very long and the various other purifying influences exceptionally potent.

The Self-Purification of Lakes and Reservoirs.

The same natural influences that tend to purify running streams are also at work in the waters of lakes and reservoirs, and in most cases with better results.

This is so far true that an eminent sanitarian has said that the saying that "running water purifies itself" should be reversed and made to read "standing water purifies itself."

Dispersion. When sewage is allowed to flow into a lake its bacteria gradually become dispersed, or diluted, by the action of horizontal currents induced by the wind, and by vertical currents due to differences in temperature and density of the water at different depths. Dispersion makes the water less and less likely to contain infection as its distance from the sewer outfall increases, and thus tends to reduce the danger of using the water, although it is not a purification in the strictest sense.

Sedimentation. Sedimentation is usually much more potent in lakes and reservoirs than in rivers, and the resulting purification is correspondingly greater, while the unfavorable results of scour are less likely to occur, especially in deep lakes. Wind action may impart movement to the water near the surface of a lake, but if there is any considerable depth, the water in the lower strata may remain comparatively quiescent. Shallow lakes are often calm for short periods and sometimes for long periods, as, for instance, when they are frozen over in the winter, and this affords good opportunities for subsidence. Deep lakes become thermally stratified, and the water below a depth of twenty or thirty feet may remain practically motionless for months at a time. The summer and winter stagnation of lakes has many important bearings on the storage of water, but not the least of its influences is the opportunity that it gives for the deposition of suspended matter and for the death of any pathogenic bacteria that may thus settle to the bottom. The chance of scour must not be overlooked, however, even in a lake. Wind action often stirs the water of a shallow lake to its bottom; while between the times of summer and winter stagnation in a deep reservoir there are periods of circulation when the water at the bottom rises to the top and some of the accumulated sediment is carried upwards.

Beneficial Influence of Storage. The long storage of water in a lake greatly minimizes the danger from contamination. It has already been shown how, on standing, typhoid fever bacilli decrease in numbers in natural waters, and how after a month a body of water may contain only a few per cent of the number contained at first. The storage in large lakes often amounts to many months.

Antagonism of Microscopic Organisms. The antagonistic effect of other organisms is greater in lakes than in streams. The waters of ponds and lakes and reservoirs frequently contain algal and protozoan growths, — often to such an extent that they become offensive to sight and smell, and practically unfit for use as a water-supply. The "purging" of a lake is a common phrase used to describe these growths. It is popularly supposed that this "purging" is a natural attempt of the water to purify itself; but most water consumers will admit that if this is so, Nature has adopted a very crude and unpleasant method of securing the desired result. But there is more truth in the idea of purification by purging than might be supposed. The algæ are more or less gelatinous in character, and as they sweep through the water, driven by the winds and currents, they entangle large numbers of bacteria and destroy them. Some of the protozoa, animal in nature, actually devour the bacteria as food. It is a fact which has been frequently noted, that algæ growths tend to cleanse the water of lakes and ponds of their bacterial contents. This tendency for the microscopic organisms to destroy typhoid bacilli is of practical importance only when the organisms are present in large numbers; ordinarily it amounts to very little.

Dangers of Depending upon Storage Alone. In these various ways the storage of water in lakes and reservoirs increases its safety for domestic use. Yet one should not get the idea that storage insures complete immunity. The location of a sewer outfall and a waterworks intake in a lake may be such that between the two the advantages of storage are not secured; currents may carry pollution from one to the other. An impounding reservoir may have a stream flowing in at the upper end and a waterworks gatehouse at the lower end; this reservoir may provide a large storage and act as an important sanitary safeguard during the greater part of the year, and yet at times of large stream flow it may permit the water to flow through so rapidly that the storage is reduced to a brief interval, with consequent danger to the water consumers. This has been found to be true even in reservoirs of very large size. In a dry season also the reservoir may be almost empty, and then even a small rain may suffice to cause the water to flow rapidly across from the inlet to the outlet.

Unless the conditions for stream purification or for long storage in large reservoirs are very exceptional, the only adequate safeguard against a polluted drinking-water is artificial purification, — that is, filtration.

Self-Purification in Conduits and Pipes.

Some of the discontaminating influences above mentioned continue to act after a water has entered the conduits and pipes of a distribution system; namely, sedimentation, the natural death of the bacteria, and the antagonistic influences of other organisms. If the water contains many microscopic organisms, that is, algæ and protozoa, the walls of the aqueducts and the interior surfaces of the pipes may become coated with fresh water sponge or with "pipe moss," a fibrous mass of animal organisms known zoölogically as the Bryozoa. These bryozoa consume the microscopic organisms as food, and thus tend to reduce the number of bacteria. The chemical effect of the iron deposits may also have some inhibiting effect on the bacteria. It is a matter of common observation that the numbers of bacteria in water decrease somewhat in passing through the pipes of a distribution system, the numbers of B. coli decrease, and presumably the number of typhoid bacilli in an infected water would fall off in the same way, so that the most intense infection would be likely to be nearest the source of supply.

Dead Ends. It is commonly thought that the "dead ends" of a waterworks system are the frequent cause of disease. They do occasionally furnish water of bad quality,—water which is dirty and ill-smelling,—but there is little or no evidence that such water is the cause of typhoid fever. If the typhoid fever germ is affected by the different factors in the manner which has been described, it may be said of dead ends that, so far as this disease is concerned, the deader they are the better.

As a rule, the purification that takes place in the pipes of a distribution system is practically negligible, although it is of some theoretical interest.

Longevity of the Typhoid Bacillus in Ice.

Laboratory experiments have shown that in a general way the longevity of the typhoid bacillus decreases gradually as the freezing temperature is reached; that whereas an exposure of two weeks may be required to reduce the number of typhoid germs by 90 per cent in water at 70 degrees, only a day or two may be required if the temperature of the water is at 0 degrees or near it.

In ice the mortality is even greater. Sedgwick and Winslow have shown that after 24 hours the reduction amounts to about 90 per cent, and after two weeks or more to 99 per cent. Hence, contaminated ice cut in January, may be used in July with only one per cent of the chance of danger that would be run by using the ice when freshly cut.

Natural Ice. Furthermore, in the natural process of freezing, it has been found that about 90 per cent of the bacteria in the original water are excluded, or frozen out; that is, the ice which forms over a polluted water is only 10 per cent as impure as the water itself. The combined effect of this mechanical elimination of impurities by freezing and the death of the bacteria during storage between winter and summer tends to reduce the practical danger of ice infection to an almost negligible quantity, provided the ice is properly harvested and stored.

Unfortunately this is not always the case. The flooding of ice fields by making holes in the ice, causes the entire body of flooded water to be frozen into the cake, thus eliminating the natural purification by exclusion. Such flooded ice harvested from a polluted source may be very objectionable. Ice from a shallow water may also be dangerous, as the entire body of water may freeze solid, thus rendering the bottom ice impure. Fortunately these errors have a natural corrective. Flooded ice is often dirty, and snow ice does not keep well. Large ice harvesters plane off the dirty ice and snow ice. If one follows the practical rule of never using in the household ice that is dirty, the danger of contracting typhoid fever from it may be substantially eliminated.

The experiments of Sedgwick and Winslow already alluded to showed that a few of the typhoid bacilli experimented with had a power of resistance much greater than the general average, and remained alive for a number of weeks. Prudden and other observers have also noted their power to withstand freezing. The transmission of typhoid fever by ice through these resistant residual cells is, therefore, a possibility which ought not to be lost sight of; and while the author believes that it rarely occurs, it may account for some of the cases of obscure origin.

Artificial Ice. It is natural to think that artificial ice "made from distilled water" is much less likely to be infected than natural ice. This, however, is not necessarily the case. From the foregoing statements it is seen that the "time element" is a great factor in making ice safe for use. In the case of natural ice element this is long; in the case of artificial ice it is short. The distilled water used in making the ice may be pure, but there are opportunities for the receptacles used in ice-making to be contaminated. The author knows of instances where men with their dirty boots walked over these receptacles in the freezing rooms, and where privies have been located almost in the rooms where the ice is made. Spring waters or well waters are often used in the manufacture of ice, and these may be subject to contamination. The plants for manufacturing ice ought to be subject to rigid inspection on the part of the health authorities.

Handling of Ice. Perhaps, after all, the greatest danger from ice is in the handling during distribution. It is walked over in the ice-houses, peddled through dusty streets, left on the sidewalk or floor, handled by servants, carted around in railroad stations, and dumped by laborers with dirty hands directly into drinking-water tanks, and in many ways subjected to chances of infection. Of course, the outer layers of ice are constantly melting, and this, in a measure, acts as a natural protection from dirty handling; yet some danger is likely to remain.

Longevity of the Typhoid Bacillus in the Soil.

The life of the typhoid bacillus when buried in the soil under natural conditions is probably short. This has been demonstrated by numerous experiments, although experiments have also shown that in sterile soils the germ may live for a long time. The soil is the great repository of bacterial life. Garden mold is teeming with untold myriads of bacteria of many kinds—"soil bacteria" we call them. They serve many useful agricultural functions, and among these the production of toxic substances, which tend to destroy such pathogenic organisms as that of typhoid fever, is not the least important. Most of the fundamental instincts of mankind have a scientific foundation; and the instinct to bury excrementitious matter, common to many animals as well as man, is no exception to the rule.

It is because of this action of the soil that disposal of the stools of typhoid fever patients by burial in the earth is recommended. It is the soil bacteria near the surface of the ground which are chiefly responsible for the destruction of the typhoid bacilli; hence care should be taken not to bury the stools too deep, or to have them too concentrated. It is not sufficient to throw them into a hole dug in the ground; the earth should be thrown over them. A new hole should be used each time.

Typhoid bacilli thrown on the top of the ground are likely to survive longer than if buried, but between drying and the effect of sunlight and other agencies, they ultimately succumb. The practice of throwing the stools and urine of typhoid patients on the surface of the ground is highly dangerous on account of the possibility of the bacilli being washed into some well or watercourse, or of being picked up by flies.

This destructive action of the soil on typhoid germs must not be depended upon too implicitly, and care should be taken that burial is not made too near a well or a stream used for drinking. Dry sandy soils contain few soil bacteria, and in gravelly soils or badly cracked clay-beds, percolation may take place rapidly and well water contamination may result.

Cesspools usually extend into the ground to a depth where there are few soil bacteria. Unless made water-tight, the liquids, with more or less suspended matter, bacteria included, leach away into the ground. In coarse, porous soil these germs may percolate for many feet, possibly to pollute some water-supply, as elsewhere described. Where the cesspool is old, the soil around it may become foul, and lose some of its natural power of purifying the leaching sewage. In fine-grained sandy soils, however, a large amount of natural purification takes place around a cesspool.

Longevity of the Typhoid Bacillus in Milk.

The behavior of the typhoid bacillus in milk is very different from what it is in water. In water it gradually dies out; in fresh milk, on the contrary, it probably multiplies. At least, milk is a favorable culture medium for most bacteria. As drawn from the cow it contains very few bacteria and may be almost sterile, but twenty-four hours' standing at room temperature suffices for the bacteria present to develop a thousand-fold. The milk sold in most of our cities contains anywhere from tens of thousands to millions in each teaspoonful. It may be readily imagined, therefore, that milk infected with typhoid fever germs may be highly dangerous by the time it is used.

In epidemics due to milk, the suddenness and violence of the attacks have been often noticed, — indicating, apparently, an intense infection.

Of the bacteria likely to be found in milk, the lactic acid bacteria which bring about the souring or curdling, appear to thrive most luxuriantly. Often they seem to develop to such an extent as to practically subdue all other forms, including pathogenic forms. The typhoid fever bacillus does not curdle milk. So far as typhoid fever is concerned, therefore, sour milk is not more dangerous than sweet milk; it may be even less so. On the other hand, milk is not good merely because it is sweet.

Experiments appear to indicate that typhoid fever bacilli do not readily multiply in milk already soured, that is, in milk which contains enormous numbers of the lactic acid bacteria, as the acid or some other antagonistic substance, seems to inhibit their growth. It is said also that they do not grow in butter or cheese for similar reasons.

The viability of the typhoid bacillus in milk needs a far more careful study than it has ever received. Our knowledge of its fate in milk is not nearly as extensive as our knowledge of its fate in water.

Longevity of the Typhoid Bacillus in Oysters.

A number of investigations have been undertaken to determine the longevity of the typhoid bacillus in oysters, but most of the tests have been rather unsatisfactory. Generally speaking, they indicate that the bacillus is able to live for periods ranging from a few days to two or three weeks. Judging from some of the experiments, and reasoning by analogy from other organisms, there is reason to think that the germs do not multiply in a live oyster, but that they may grow rapidly in a dead one. As the bloating of an oyster undoubtedly has an injurious effect upon its physiology, it may be that the infection of a bloated oyster is a more serious matter than the infection of one of natural growth. The experiments indicate, however, that the longevity of the typhoid germ in oysters is sufficient to more than cover the interval that usually elapses between the gathering of oysters and their consumption.

Longevity of the Typhoid Bacillus in Flies.

Flies may transmit the typhoid bacillus in two ways: namely, by the fecal matter containing the germ adhering to the fly and being mechanically transported, or by the fly taking the germ into its digestive organs and depositing it with its excrement. An interesting illustration of the first method of transmission was the experiment made by someone who sprinkled lime in a privy vault and exposed a chocolate frosted cake in front of the kitchen window not far distant; it was not long before the white tracks of the flies were found on the cake. A more definite experiment was that made in Chicago where flies caught in certain privy vaults were examined and found to contain B. typhi.

Some experiments have been conducted to ascertain the duration of life of the typhoid bacillus in the bodies of flies fed on infected milk. These experiments are not wholly satisfactory, but Fischer states that he found them there twenty-three days after infection.

Longevity of the Typhoid Bacillus on Fabrics.

Although typhoid fever is not conveyed by the clothing, taking this expression according to popular usage, yet the clothing of a typhoid patient may become infected and the infection may be imparted to the laundress or to some comrade. In an army camp or in the close quarters of a tenement house, this may be an important matter. Firth and Horrocks have found that the germs of typhoid fever could be recovered from khaki fabrics and from common blue serge two or three months after infection.

CHAPTER V.

LINES OF DEFENSE AGAINST THE TYPHOID BACILLUS.

A WELL-PROTECTED fort has more than one line of defense. Besides the ramparts behind which are mounted the disappearing guns, there is likely to be, in times of war at least, a line of earthworks, — perhaps more than one, — and beyond that various outposts, pickets and scouts. Within, the magazine is protected against fire and against stray shots, while the officers' quarters are guarded by sentries. No other figure so well describes the precautions which must be taken against typhoid fever and diseases of its type. No man in time of war can alone protect himself. Battle-ships and forts are needed to keep the enemy at long range; but once the city is invaded, the individual can, in a measure, protect his own hearthstone and the members of his own family.

Coöperative Work Necessary. Let it be emphasized again that the fight against disease is coöperative work, and that just as the public authority, the household, and the individual have separate parts to play in preventing the germs from scattering, so also they have separate functions to perform in defending against the bacilli at large. These three lines of defense, as they may be called, are illustrated by three circles in the diagram in the frontispiece. The largest illustrates the work of the public authorities, the health department, water department, etc., which affects the entire community, and which, if properly done, will forestall to a great extent, but never completely, the necessity for the inner lines of defense. The middle circle illustrates the care that must be taken by each household, while the inner circle stands for what the individual can do in the way of self-protection.

First Line of Defense.

Public Responsibility. Continuing our figure, it may be said that the first duty of a board of health is to spy out the enemy and give warning of its approach, and to act as a bureau of information on the prevalence of infectious diseases in the community.

In most states there are laws compelling attending physicians to report contagious diseases to some local health authority, but, as has been said, these laws are almost never lived up to. This is partly due to carelessness on the part of physicians, and partly to laxity on the part of the authorities; but it is also due to the frequent uncertainty of the physician as to the nature of the disease and to the opportunities for criticism that would arise in case of error, physicians apparently preferring to encounter the mild impersonal wrath of the law than the personal displeasure of the patient and his family. It is a well-known fact that during an epidemic of typhoid fever, for example, the ratio of reported cases to deaths is much higher than when there is no epidemic, — often it is more than double, — showing how public interest stimulates the physicians to their sense of duty.

Value of Statistics. It is not during an epidemic, however, but rather before the epidemic occurs that the reports are of real value. Too often the community realizes that disease has become epidemic before the fact is reflected in the health department records. It may even happen that the cases may be reported to the authorities and yet lie idle and dormant in the pigeon-hole of some negligent clerk until they are routed out by a newspaper reporter or by some physician or citizen more observing than others. Morbidity statistics unless promptly used are worthless. It is not enough that they be accurately and properly reported and recorded; they must be constantly under observation with a view to the immediate detection of an abnormal increase. And any abnormal increase, no matter how small, should be investigated, as one can never tell whether it may not be the beginning of a serious epidemic. Health statistics are too often treated as facts for history, whereas they ought primarily to be treated as facts for prophecy. Many an epidemic might have been checked half-way by a more early recognition of the fact that there was an epidemic.

Public authorities must not wait for epidemics before establishing their lines of defense, although at such times the lines must be more tightly drawn. There are certain routes by which the typhoid germ travels that must be constantly defended. The protection of the purity of the public water-supply, the protection of milk and various foods, must continually be maintained. Some of this protective work has already been alluded to in connection with the three barriers against the scattering of the germs. The topics which require special mention here are the purification of water, the certification and pasteurization of milk, and the safeguarding of other foods.

Public Water Supplies. If a public authority undertakes to supply a city or town with drinking-water, it would seem to be self-evident that upon such authority rests the responsibility of seeing that the water is pure and wholesome. If the supply is furnished by a private water company, it would seem as if the burden of protecting the consumer against water-borne diseases should rest with the company. Yet how lightly are these burdens borne! In how many cases have official neglect and corporate greed resulted in wide-spread disaster! In how many cases has the failure to appreciate the besetting dangers of pollution resulted in epidemics of appalling magnitude! In how many cases have sanitary reforms been postponed because of politics, because of quarrels between conflicting interests, because of failure to choose between one of two or more plans, each of which might have brought relief, or because of failure to appreciate the public danger!

Not long ago a suit was brought against a certain western city to recover damages because of the death of a person who died from typhoid fever, caused, it was alleged, by the infection of the public water-supply. The suit was lost. There are some who believe, however, that the time will come when such suits will not be lost; when the public authorities will be held legally as well as morally responsible for deaths due to infected water. If a city is responsible for the condition of the public highways, and is liable in case an injury results from neglect of proper care, how much greater the responsibility when the neglect puts in jeopardy the health of the entire community.

Filtration Increasing. It is gratifying to see that so many of our American cities have awakened to the need of properly safeguarding the quality of the water supplied to the public for drinking purposes. During the last five years filter plants have been built and put in operation in Charleston, S.C., Youngstown, Ohio, Washington, D.C., Providence, R.I., New Haven, Conn., Watertown, N.Y., Indianapolis, Ind., Philadelphia, Pa., New Milford, N.J., Brooklyn, N.Y., and Binghamton, N.Y., Little Falls and Hackensack, N.J., Chester, Pa., and elsewhere. Large filters are under construction in Philadelphia, Pittsburg, Cincinnati, Louisville, Columbus, Ohio, and New Orleans, and filter plants are being enlarged or improved in Bangor, Me., Albany, N.Y., Yonkers, N.Y. In other cities, such as Troy, New York City, Toledo, Ohio, Oakland, Cal., Grand Rapids, Mich., Wilmington, Del., Minneapolis, Minn., Trenton, N.J., Lynn, Mass., and Lancaster, Pa., they have been recommended, and projects are under consideration. Chicago has spent enormous sums to divert her sewage out of Lake Michigan. Cleveland, Buffalo, and Erie have extended their intakes farther into the lakes. Oswego is preparing to do so. Polluted supplies have been abandoned and purer sources substituted in Newark, N.J., Jersey City, N.J., Augusta, Me., Waterville, Me., and Hudson, N.Y., while renewed attention is being given to the elimination of pollution on the watershed in Boston, New York, and Baltimore. Many other cities might be named in each group.

Standards of Purity Rising. The movement to secure pure water is widespread. Standards of purity are becoming higher. Waters that ten years ago would have been called good are now being subjected to purification. Not only municipal authorities but private water companies are building filters, for it has been found that to sell pure water pays better than to sell impure water. In recent appraisals of waterworks properties passing from private to public ownership, the award has been lowered in cases where the water was polluted by an amount approximately equal to that required to purify the water or to obtain a substitute supply of good quality. In other words, depreciation due to pollution has been recognized by the courts.

Safety of Ground Waters. In view of the strong drift towards filtration, and of all that has been written on the relation between impure water and the public health, it is not necessary to discuss this subject in detail. It may be said in passing, however, that ground waters taken by means of artesian or moderately deep driven wells are almost invariably safe against infection: the natural filtration which the water receives in the ground is almost invariably a sufficient protection. Wells in populous districts, where the soil is porous or fissured, as in limestone regions, may become dangerous through underground pollution.

Dangers from Surface Water. Surface waters are safe or unsafe according to the population on their watersheds and their freedom from contamination, and in proportion to the time of stream-flow or storage between any possible sources of infection and the city mains. The reason why the stored water of large lakes or large reservoirs is safer than water taken direct from streams has been already described. Most surface waters are open to accidental contamination, so that they can never be considered as absolutely safe, even though the population on the watershed be sparse.

Sanitary Supervision of Watersheds. Much can be done towards making surface waters safe by exercising a sanitary supervision over the watershed, eliminating all direct pollution and taking all possible precautions against accidental contamination, and by constantly keeping watch over the quality of the water by the employment of inspectors and water analysts. In some states there are laws against the direct discharge of sewage or fecal matter into streams used as water supplies. In others there are laws regulating the distances within which privies or water-closets may be located from streams and reservoirs. Some cities preserve the quality of their water-supplies by assuming the duty of caring for the privies near the streams, or by contributing to the expense of sewage disposal systems. It has been suggested that cities should stand the expense, or a part of the expense, of the disinfection of sewage discharged into the streams tributary to its water-supply. The equity in these matters is difficult to establish, but it is likely that in time general doctrines based on the principles of the common law will become recognized.

In some of the larger cities laboratories for water analysis are maintained and samples analyzed at frequent intervals. This work is to be commended, but analyses should not be regarded as a fetich or allowed to take the place of active protective work on the watershed. An individual does not gain in weight by weighing himself at frequent intervals; and analyses should be used as measures of the protective work and as warnings of sudden dangers.

Recognizing that it is infection rather than contamination that brings real danger, some water departments make arrangements with physicians who practice among those dwelling on watersheds to report any cases of typhoid fever that occur. At Waterbury, Conn., the watershed is placarded with cloth signs stating that a reward of ten dollars will be paid to any person who first informs the City Engineer or Superintendent of Water Works of a case of typhoid fever anywhere on the watershed. Printed postal cards addressed to the superintendent are furnished to all physicians in towns bordering upon the watersheds with the request that they fill in the blanks and mail them whenever they are called to a case of intestinal disease. On receipt of such a card the city undertakes the duty and stands the expense of disinfecting and disposal of fecal matter. A somewhat similar system is in vogue in Springfield, Mass. The reward there is only two dollars a case, but it is given for diarrheal diseases as well as for typhoid fever. This system has much to commend it and is likely to increase in favor.

[1] These facts were kindly furnished by Mr. R. A. Cairns, City Engineer.

The danger of all such methods of supervision, however, is that they often do not give the needed information until after the evil has been accomplished.

Effect of Filtration. Filtration affords the safest protection of surface waters against water-borne diseases. This has been proved by long experience abroad, and data illustrating this truth are being constantly accumulated in this country. In Lawrence, Mass., the typhoid fever death-rate, after the city filter was put in use, fell from an average of 121 to an average of 26 per 100,000. After the construction of the filter in Albany, N. Y., it fell from 104 to 26; in Binghamton from 49 to 11; in Watertown, N. Y., from 97 to 27. In Philadelphia the death-rate has greatly decreased in those sections of the city where the filters have been completed. Numerous other instances are cited in Chapter X.

There are two principal systems of water filtration: sand filtration, that is, filtration at a slow rate through beds of rather fine sand, sometimes acres in extent; and mechanical filtration, which consists of a rapid straining of the water through coarser sand after a process of chemical coagulation. Each of these two methods has its own field of special usefulness. Each is able to bring about a satisfactory degree of purification if properly carried on. Sand filtration is especially useful and economical for clear and colorless waters; mechanical filtration is demanded for waters which are either very muddy or very much stained. Sometimes the choice of the two systems is merely a question of cost, and in most cases complicated engineering matters are involved. These demand the services of an expert. Filters purchased and installed as one buys a ready-made machine are almost never as permanently satisfactory or as economical as those designed by a competent engineer to fit the particular local needs.

Vended Waters. In many cities, especially in those where the public water-supply is not satisfactory, the use of vended spring waters is very common. This practice is not altogether as sanitary as most people suppose. Occasionally the much advertised spring waters are more unsafe than the public water-supply, while too often insufficient care is given to the receptacles used for distribution. In some cities where analyses of spring waters have been made, the results have been anything but satisfactory. It would be unjust to condemn all vended waters, as most of them are probably of excellent quality, but the matter is one which ought to be carefully looked after by the health authorities.

Dangers from Dirty Milk. Milk is a universal food product, and one which enters into the dietary of almost every family. Its cleanliness is of the utmost importance. Dirty milk is dangerous, and statistics show that it is a most important vehicle of infection, not only for typhoid fever, but for many diarrheal troubles, for scarlet fever, and probably for other diseases. While the sale of milk is almost universally in private hands, yet, inasmuch as the purchaser in a large city is powerless to protect himself, the supervision of the milk becomes a proper function of the board of health.

Milk may become infected with typhoid fever in various ways. The hands of the milker may convey the infection, the milk cans may be washed with water from a contaminated well, or infected water may be added to the milk. Handling at the milk depots and pouring from can to can offer opportunities for the introduction of typhoid germs, and the passing of glass bottles from house to house without efficient washing and sterilization may do the same. The glass milk jars are even taken into the sick-room by the poorer classes, who find them convenient receptacles for daily use as well as for transportation. Physicians have reported that typhoid patients have even been seen drinking from milk jars.

Certified Milk. Certified milk is milk derived from farms which have been examined by some authorized body and pronounced satisfactory, the farms being kept continually under supervision and the milk being regularly analyzed. Certified milk is sold in sealed sterilized glass jars, properly labeled. It commands a higher price than ordinary milk, and is usually worth the money, not only because it is safer, but because it is richer.

Inspected Milk is a grade somewhat less carefully supervised than certified milk, but better than ordinary milk.

Pasteurized Milk. Pasteurized milk is milk that has been subjected to heat, but not boiled. The temperature is raised to 160 degrees F., or thereabouts, and allowed to remain for a few minutes, after which the milk is quickly cooled. Pasteurization effectually destroys the typhoid germ, as well as most other germs which do not form spores. It is therefore a safeguard against most milk-borne diseases, and for that reason is strongly advocated by sanitarians. That the general use of pasteurized milk would materially improve the health of our cities and greatly reduce the number of deaths of young children, is evident to any one who has studied the results already accomplished. On the other hand, many physiologists claim that pasteurized milk is not as wholesome as raw milk, and is less easily digested and advocate the supervision of the sanitary conditions at the milk farms in place of general pasteurization.

That pure raw milk is better than pasteurized milk will be generally admitted; the difficulty is in making certain that the raw milk is pure. Although there are still differences of opinion as to the best way of dealing with the milk problem, the cause of pasteurization seems to be steadily gaining ground. Before many years the general pasteurization of milk in large cities is likely to be as common as the filtration of water.

But pasteurization must not be allowed to cover the neglect of inspecting the farms from which the milk-supply is obtained. In many states and cities more stringent laws covering the sale of milk are urgently needed.

Regulation of Oyster Culture. Oysters naturally grow in pure water. Like other mollusks, they develop from eggs. Native oyster beds are usually located where there is a rocky bottom, or where there are hard substances to which the "spat" may become attached. It is said that natural beds furnish about half of the oysters used in the United States; the remainder comes from artificial beds to which the oysters have been transplanted in order that they may grow to better advantage. The food of oysters consists chiefly of diatoms and other microscopic organisms and suspended matter found floating in sea water; and, in general, the larger the amount of this microscopic life, the more rapid will be the development of the oysters. The oyster eats by taking in large volumes of water, straining out the organisms as the water passes through the gills. Consequently any bacteria that may be in the water pass in a continuous procession in and through the oyster.

In order to supply oysters of large size, it is a common custom to fatten them, or float them, by immersing them in brackish water before they are sold; and, unfortunately, it is a common custom to carry on this process in localities which are subject to sewage pollution. It is chiefly to this custom of "bloating," or "plumping," or "floating" oysters, or "letting them drink" in polluted water, that the danger of infection lies. The question is often asked, "How can one tell whether or not an oyster has been floated?" The answer is, "It cannot be told by the ordinary consumer," and not always by an expert. As a general rule, however, small, dark-colored salt oysters are safer than large, light-colored fresh oysters which are flabby and have the gills and the muscles swollen.

The viability of the typhoid bacillus in oysters has been already referred to, and on subsequent pages references will be found to outbreaks of typhoid fever which have been due to the use of infected oysters. Suffice it to say here that the practice of using oysters harvested near the mouths of sewers, or fattened in the waters of streams and harbors subject to sewage pollution, is attended with real danger to the public health.

In some states, as, for instance, Massachusetts and

Connecticut, laws have been passed restricting the cultivation of oysters, and similar laws are under consideration elsewhere. The matter is one where the health authorities should assume control. In some localities the sale of oysters should be prohibited; in others it is probable that the licensing of satisfactory layings would be the most practicable method. It is possible also that some plan by which good oysters may be certified in the same way as milk is now certified would yield favorable results, and be a benefit not only to the public but also to the dealers.

In justice to the oyster dealers, it ought to be stated that they are beginning to appreciate the dangers that may come from infected oysters, and many marketmen refuse to handle oysters from suspected sources. If the oystermen who carry on the business of floating their product in polluted waters ought to be forced out of the market, those dealers who obtain their supply from good sources ought on the other hand to be encouraged. Oysters are an important article of food, and the oyster industry is one of far greater magnitude than most people appreciate, — amounting in value to nearly one-third of the fishing interests of the country. It is right to emphasize the danger from oysters, but it is not right to produce a general "scare," for, as a matter of fact, oysters probably cause not more than a tiny fraction of the typhoid fever of the country. In the best clubs and hotels nowadays the stewards are careful where they secure their supply of shell-fish.

The question naturally arises, "Does not the cooking of oysters destroy any germs that may be present?"

Numerous experiments have been made to answer it, and these have shown, as one might expect, that the application of heat does to a very considerable extent render the oysters safe, — yet not completely so. The result depends upon the amount of heat to which the oysters are subjected and the time of exposure to this heat. "Scalloped" oysters are exposed to a rather high heat for a period of twenty minutes or more, and, when thus cooked may be considered as quite safe. Fried oysters are also raised to a high temperature in hot fat, but the period of exposure is not as long. Stewed oysters or oysters cooked in "fancy roast" receive still less heat, and experiments have shown that often the heating is not sufficient to kill all the bacteria present. Consequently oysters from polluted sources thus cooked cannot be considered as wholly free from danger. Steamed clams also may be dangerous, as the amount of heat to which they are subjected is comparatively small. Lobsters, on the other hand, require considerable heat to cook them properly, and consequently any pathogenic bacteria that may be present are quite sure to be killed.

Supervision of Food Supplies. Typhoid fever may be transmitted by other foods than milk and oysters. A number of outbreaks have been reported in various parts of the country, caused by the use of infected fruit and vegetables. There seems to be no reason why a typhoid patient who works in a bake-shop or a restaurant, or who otherwise handles food, may not scatter infection in this manner.

These vehicles of infection are so numerous that it hardly seems practicable to establish any special restrictions in regard to them. What should be done, however, is to have each case of typhoid fever investigated as soon as reported, and if it is found that the patient has been engaged in any occupation which would permit of the scattering of typhoid fever germs, steps should be taken to stop the mischief as far as possible. The proper course to be adopted will naturally suggest itself in each particular case.

Educational Work of Boards of Health. Not the least important of the work of boards of health is the education of the public as to the manner by which typhoid fever is conveyed, and as to the means that should be adopted to prevent infection. Many of the state and local boards of health now issue weekly or monthly bulletins, which are scattered broadcast to physicians and others. Such publications, if properly edited, cannot fail to be beneficial to the cause of sanitary science. In some states regular conventions of health officers are held, at which addresses are made by experts in various lines of work. The conferences of the health officers of Vermont and New York may be taken as models, and the practice is one worthy of being adopted in all states. The interest taken in sanitary matters by women's clubs and civic organizations, and the discussions which are found in the public press, are agencies destined to have a widespread influence. If some of the simple sanitary precautions against infectious diseases were taught in the public schools, it would do more to improve the health of the children than any amount of study of physiology or of the dangers from the use of alcoholic liquors. It would seem proper even to carry this educational campaign into the churches, and through them to the "submerged tenth."

The Second Line of Defense.

Household Responsibilities. The responsibilities of the household in warding off typhoid fever may be summed up in the word *cleanliness,* — clean premises, clean houses, clean water, clean food, and clean persons.

Many of the things which the board of health does on a large scale, the householder must do on a small scale. He must see to the purity of the well, provide screens for the house, the privy, and the stable, and look as carefully as circumstances will permit to the source of foods which are used uncooked.

The Country Well. Well waters are generally safer than they have been given credit for in sanitary literature, but polluted wells are very numerous, especially in thickly settled districts. Most wells which have been the cause of typhoid outbreaks have been contaminated from the top; that is, by the inflowing of polluting matters over the curb. Cases where outbreaks of disease have been due to infective matter passing through the soil are rare except where the soil is very open, or where crevices in limestone rock or clay abound. Sandy soil is a good filtering material; and where a well in such soil stands at the center of a circle twenty-five or fifty feet in radius within which there are no privies, cesspools, sink-wastes, or other sources of contamination, the water can usually be depended upon as being fit for domestic use, — provided, of course, that the top of the well is properly guarded against surface wash. No general rule governing the permissible relative locations of well and cesspool can be given, as local conditions as to the nature of the soil, the slope of the ground, the level of the underground water, etc., must be taken into account. In case of doubt as to the influences of a cesspool on a well, it is best to employ a bacteriologist to make an inspection of the site and take a sample of water for analysis. In some states analyses are made, on request, by the board of health, but in the absence of data regarding the surroundings, such analyses cannot be properly interpreted.

Wells should be cleaned out more frequently than they usually are. Dust, leaves, pollen, insects, etc., all contribute more or less organic matter which may injure the quality of the water, though without necessarily introducing infectious matter. If a well water has an unpleasant odor, it is almost always the case that the well needs cleaning, or that the water is being contaminated.

The old-fashioned well, with open top and the "old oaken bucket," is unsatisfactory on hygienic grounds.

Boiling the Water. If the public water-supply is open to suspicion, the householder still has a remedy. A polluted water may be rendered safe by boiling, and this is the best course to adopt in case danger is feared. Distillation is a safe but troublesome process. Boiling for five or ten minutes offers the best protection, and boiled water aërated and stored in bottles in the ice-chest is by no means unpalatable.

House Filters. House filters of the best earthenware type also render a polluted water reasonably safe. A good filter, however, is expensive; and in order that purification be satisfactory it is necessary to maintain an inconveniently slow rate of filtration, and to keep the filter scrupulously clean. Cheap house filters of the sand or charcoal type, and even good filters left to the tender mercies of the ordinary servant, are worthless, and may do more harm than good.

Pasteurization of Milk. The pasteurization of milk in the household is made necessary by the failure of the authorities to properly safeguard the supply. It is always a wise precaution in large cities during hot weather, when the difficulty of delivering milk of satisfactory quality is greatest. Whether or not pasteurization is advisable at all times is still an open question. In the case of some children cooked milk seems to cause physiological disturbances which are probably quite as great as those due to the use of milk of high bacterial contents. From the standpoint of infection, however, there is no doubt as to the merits of pasteurization.

Screening the Windows. Effectual screening is a sanitary measure, the importance of which is being recognized more and more each year. Screens are designed to keep away troublesome insects, such as flies and mosquitoes. The history of screens would make an interesting story. In former times it was a common custom to leave the houses unscreened, but to use little hemispherical screens over articles of food on the dining table. Some restaurants still adhere to this method. These small fly-guards became unnecessary when screens began to be used on the doors and windows of houses. The modern theory of screening, is to put the bars over the breeding-places of the insects, — over privy vaults and cellars where manure is stored, on the doors and windows of stables, on water-butts and other breeding places of mosquitoes.

The war against flies is a reform which is sure to be taken up in earnest before many years. Thus far the housewife has striven valiantly, but in vain, against a host. She has been like Mrs. Partington trying to sweep back the Atlantic with a broom. But the fight of the future is not to be fought by the housewife with her wire brush and sticky paper. It is to be made against the breeding-places.

The task is not so hopeless as it at first appears, especially when one contemplates the work done at Panama in the extermination of mosquitoes, and in Manchuria during the Japanese-Russian war in the elimination of flies.

All of these reforms and minor sanitary improvements necessary to eliminate typhoid fever from the rural districts will be very slow, and difficult to secure, — better well waters, better methods of sewage disposal, better constructed privies, greater care in the disposal of cesspool contents and sink-wastes, better methods of handling manure, more thorough screening of houses, etc. These can come only by patient popular education. If the problems of the city are more difficult than those of the country, they are also more fully appreciated and more amenable to concerted action. The problems of the city are to be solved by a few specialists; those of the country by many individual laymen. It will not be long before the cities of the United States will have more or less completely removed the principal causes of typhoid fever; but the burden of the rural typhoid must be borne by country doctors and town officials for many years to come, and they deserve the fullest support and coöperation on the part of the general health authorities. The sanitary problems of the farm are by no means trivial or unimportant to the nation. It is "the constant dropping that wears away the stone."

Third Line of Defense.

Personal Responsibility. Finally, what can the individual do to protect himself from typhoid fever? Really, very little. There are certain precautions that can be advised, but they are at present scarcely more than general platitudes.

The Health Tone. Most important, probably, is the maintenance of a good "health tone." The human mechanism, when it is in perfect physical condition, has powers of resistance which are not yet fully appreciated. A lowering of the health tone lessens these powers of resistance. Fatigue, worry, nervous exhaustion, indiscreet eating and drinking, the use of improperly cooked or impure foods, tend to derange the digestive processes and thereby influence the secretions poured into the intestinal tract, modify the bacterial conditions which exist there, and make it easier for the germs of typhoid fever and dysentery to gain a foothold. This subject is still shrouded in mystery, but each new research seems to strengthen the general proposition that minute physiological disturbances may be the indirect cause of serious disease.

One way in which the fullest advantage may be taken of the protecting influences of digestive secretions is to drink water or milk, or eat food the purity of which is open to question, at the end of a meal rather than at the beginning, or, as some one has facetiously stated it, "Never eat on an empty stomach." The reason for this is that during digestion the flow of gastric juice is increased; hence, typhoid germs taken into the system after digestion has begun stand less chance of running the gauntlet of its enemies in the stomach and upper intestines than at the beginning of the meal. When the digestive faculties are dormant the germ is more likely to find conditions favorable to development. Although little has been said about it in the text-books, and although it has not been scientifically demonstrated, many physiologists apparently believe that there is much truth in this theory.

Risks of Traveling. The individual can to some extent protect himself by the avoidance of known typhoid fever risks, especially when traveling. To drink the city water at the present time in Philadelphia or Pittsburg, or in any other city where the supply is notoriously polluted, is to take an unwarranted risk; to eat oysters in cheap restaurants in New York or Baltimore, where the supply is partly derived from contaminated sources, is also a risk; to drink milk at an ordinary restaurant is a risk. Many traveling men have come to understand these dangers and to avoid them. The practice of scraping celery before eating it; of removing the peel from apples; the custom of washing the hands before a meal, and other matters of ordinary cleanliness, are measures which tend unmistakably to the avoidance of infection.

Nostrums. It hardly seems necessary to caution the reader against the use of patent nostrums advertised to prevent or cure typhoid fever or to demonstrate the absurdity of such statements as that a little lemon juice put into a glass of water or put upon oysters will kill any typhoid germs that may be there. The idea that tobacco smoking and that mixing an alcoholic beverage with water insures safety is another instance where the "wish is father of the thought." Lemon juice and tobacco smoke and alcohol are indeed factors that tend to destroy bacterial life, but used in the ordinary way their actual influence in this direction is small. In illustration of this it is only necessary to refer to what has been said about resistant residual cells and about disinfection.

CHAPTER VI.

TYPHOID FEVER STATISTICS.

We now come to the mathematics of typhoid fever, a subject interesting chiefly to the specialist, and naturally considered as dry; yet to one who takes pains to understand the statistics, and who has the imagination to look beyond the figures and see the facts for which they stand, these records of death tell a wonderful story. They measure the steady progress of sanitary science down the years, and foreshadow the coming of the day when the scourge of typhoid fever shall be all but swept away; they also reveal many a sad case of official ignorance and carelessness, and many an instance, besides, of patient and unrewarded public service. But, if the records of typhoid epidemics tell a story of shame in many an American city, they also show that our cities are learning from their experiences, and that almost everywhere there is an increasing desire to provide good water, good milk, and generally improved sanitary conditions. The statistics afford also many illustrations of cause and effect in sanitary matters, and demonstrate in striking ways the soundness of the gospel of cleanliness. The histories of typhoid fever epidemics illustrate the brilliant detective work that has been done by our sanitary experts, and show that the "bug catcher" has come to be a most important member of the community.

In a volume of this size it is impossible to give more than a condensed summary of typhoid fever statistics, to describe in an elementary way what they mean, and to guide the reader where to look and what to look for in studying the subject more in detail.

Nature of the Statistics. Typhoid fever statistics may be considered in two groups,—first, those which appertain to the individual case, and, second, those which refer to the community, the second being practically a general and condensed summary of the first. The unit data, showing when and where a patient was taken sick, and all the particulars relating to an individual case, are necessary in the study of particular epidemics, but they are of less general interest than the summarized statistics of the second group.

The statistics for the community may be subdivided into two classes, — those which relate to sickness, and those which relate to death; that is, morbidity statistics and mortality statistics. For reasons already pointed out, the morbidity records are less likely to be accurate than the mortality records, the laws regarding the filing of death certificates being much better lived up to than those requiring physicians to report their typhoid cases to the health authorities. Consequently our study will concern itself chiefly with the mortality statistics.

Death-rates. One of the terms most commonly used in sanitary science is the "death-rate." By this is meant the ratio which the number of deaths in a community in a given time bears to the living population.

The unit of time is generally one year, while the unit of population is taken as 1000, 10,000, or 100,000, according to custom or convenience. To illustrate the meaning of "death-rate": If twenty persons should die in one year in a town which has a population of 1000, the annual death-rate would be said to be "20 per 1000"; if thirty persons died in one year in a town which has a population of 1500, the annual death-rate would again be "20 per 1000"; — in other words, the calculation of the death-rate is merely one of simple proportion. The object of using the term "death-rate" is to enable one to compare on the same basis the sanitary conditions in communities which differ in population, and in the same community at different times.

When the term "death-rate" is used alone, it generally means the annual ratio of deaths from all causes to the living population. When specific diseases are in question it is customary to speak of the "typhoid fever death-rate," the "diphtheria death-rate," etc. General death-rates are usually calculated on a basis of 1000 population, as the figures thus obtained are most convenient for tabulation. Death-rates for particular diseases are sometimes calculated on the same basis or on the basis of 10,000, but it is more common to calculate them on the basis of 100,000 population, as this tends to avoid the use of decimals, and simplifies tabulation. Thus, when the average annual typhoid fever death-rate for the United States is given as 35, it means that of every 100,000 of the population 35 persons die from typhoid fever each year. All the typhoid fever death-rates referred to in this volume have been calculated on this basis.

Monthly death-rates could be calculated in a similar way, by finding the ratio between the number of deaths in the month and the living population, and expressing the result as so many per 1000, or 10,000, or 100,000. The sum of the monthly death-rates for the year would thus equal the annual death-rate, it being assumed that the population does not change. When, however, it is desired to compare the mortality in any month with the average mortality, the monthly death-rate for the month in question is multiplied by 12, so as to show what the annual death-rate would be if it were the same for the whole year as for this one month. This method is more commonly used, perhaps, than the other. It has the advantage of maintaining a single unit of comparison. Similarly death-rates may be calculated for weekly periods, and reduced to their equivalent annual death-rates.

It will be seen that there are three elements involved in the calculation of typhoid fever death-rates, — first, the number of persons who died of the disease; second, the population of the community; and third, the period of time during which the deaths occurred, generally taken as one year. The accuracy of the death-rate depends, therefore, upon the correctness of the number of deaths reported, and the correctness of the estimate of population. In the study of typhoid statistics it is important to bear this fact in mind; and, as both quantities are likely to be in error, too much attention must not be given to very slight differences in calculated death-rates.

In order to avoid errors due to incorrect population returns, the typhoid fever statistics are often figured on the basis of total deaths; that is, instead of calculating the number of typhoid deaths per 100,000 population, the rate of the typhoid deaths to 100 deaths from all causes is found. This figure may be termed the "percentage of typhoid fever." The method is useful in comparing the relative importance of different diseases. It serves as a sort of check on the death-rate.

Figures are given sometimes to show the fatality of the disease, — that is, the rate of deaths to cases.

To illustrate the meaning of these different terms, we may assume that a certain community, which has a population of 20,000, had in one year 400 deaths from all causes, 15 deaths from typhoid, and 250 cases of typhoid; then:

The total death-rate would be 20 per 1000;
The typhoid fever death-rate, 75 per 100,000;
The percentage of typhoid fever, 3.75 per cent, and
The fatality of typhoid fever, 6 per cent.

Sources of Error. One of the most important sources of error in typhoid statistics is the faulty diagnosis of the disease. The experience of the Spanish war taught that many so-called cases of malaria were really typhoid fever, while probably some cases were called typhoid fever that were really due to improper diet. Dr. Fulton, of Baltimore, has shown that this is true to-day of much of the malaria in the southern states. The cases are much fewer, however, where true malaria is diagnosed as typhoid fever. In the past, when diagnosis was based wholly on symptoms, there was some excuse for the confounding of these two diseases; but now that we have the bacteriological tests for typhoid fever, and can detect the malarial parasite in the blood by microscopical examination, such errors are in most cases inexcusable. As a matter of fact, there has been a decided improvement in diagnosis in recent years. The tendency of this more exact diagnosis has been to increase the amount of typhoid fever given in the statistics; and this fact must be borne in mind in making chronological comparison, and in comparing the typhoid fever death-rates in malarial and non-malarial regions.

Another source of error in the statistics is due to the confusion resulting from complications in the disease. It was said above that less than half of the typhoid patients who die, succumb from the direct effects of the disease; more die from the effect of the complicating, or secondary diseases. Thus, a person may get typhoid fever, and before this disease has run its course pneumonia may set in, and the patient may die from the latter cause. The physician should, of course, report this as a *case* of typhoid fever; but he may report the *death* as due to typhoid fever or to pneumonia, or he may call it, as he often does, typhoid-pneumonia. Sanitarians are at variance as to the proper course to be pursued in this case. If the pneumonia was due to an invasion of the lungs by the typhoid bacillus, the death should unquestionably be reported as typhoid fever; but if the pneumonia was due to the pneumococcus, there is more reason for calling it pneumonia, and whether it were called typhoid fever or pneumonia would probably be determined in the mind of the physician by the time that elapsed before the secondary infection took place.

It would appear to be logical to report such a case as typhoid-pneumonia, or typho-pneumonia; but this term has been so much abused, and has been so much used to describe severe cases of pneumonia where there was no typhoid infection at all, that sanitarians are now almost unanimous in condemning the use of the double term. Physicians are sometimes too explicit in reporting causes of death. For example, a lady in Maine, according to an old record in a city clerk's office, is said to have died from "typhoid fever, bronchitis, pneumonia, and a miscarriage." From the standpoint of epidemiology, it would be preferable to classify cases according to the first infection; but as the vital statistics are not to be used alone for a study of epidemics, there is some objection to this course. In important investigations it is always advisable to refer back to the original death certificates. Greater uniformity is desired in these matters, and the uncertainties are here mentioned merely to warn the reader to be on his guard in studying typhoid statistics, and not to give too much weight to published records. There has been recently organized in the American Public Health Association, a Section of Vital Statistics for the purpose of considering all questions relating to this subject.

The old records of typhoid fever in many places are liable to be in error by reason of incompleteness, and in studying the statistics it is wise to take into account the date when adequate registration laws were put in force.

In generalized statistics minor errors became less prominent, so that in spite of all the inaccuracies which the typhoid fever records of the country contain, they are sufficiently exact to show the main facts in regard to the relative abundance of the disease in different places and at different times.

Morbidity Statistics. The incompleteness of morbidity statistics of typhoid fever based on physicians' reports, is usually so great as to make them practically useless. A few examples will suffice to illustrate this:

In Brooklyn, N.Y., in 1904 there were 1050 reported cases of typhoid fever and 303 deaths, indicating a fatality of 29 per cent; in New York City (borough of Manhattan) in the same year there were 2136 cases and 309 deaths, indicating a fatality of 14.5 per cent. When complete statistics are obtained, the percentage fatality in typhoid fever almost never exceeds 10 per cent. In Waterville and Augusta, Me., where in 1902–3 statistics were obtained by a house-to-house canvass, the fatality was 8.6 per cent; in Ithaca in 1903 it was 6.1 per cent; in the United States military camps during the Spanish war it was 7.6. The fatality varies according to age, as referred to elsewhere.

When an epidemic occurs, physicians are more likely to report cases of typhoid fever than at other times when there is no excitement. Thus, in Cleveland, the ratio of typhoid deaths to reported cases in 1902 was 27 per cent; during the epidemic years of 1903–4 it was 14.5 per cent; in 1905, after the excitement had subsided, it rose to 33 per cent. It is not infrequent that health department records will show a larger number of deaths from typhoid fever than there were cases reported.

For this reason, in the study of epidemics it is necessary to take special steps to secure accurate data.

Sources of Information. Those who desire to know the typhoid fever situation in their own town or city or state, should consult the reports of the local board of health or the reports of the state board of health, if they are published; and if they are not, they should then seek the original authorities, by going to the officials charged with keeping the records of death certificates. The United States Bureau of the Census published in 1900 a rather complete series of statistics for that year for a portion of the United States known as the "registration area," and the same bureau now publishes annually the typhoid fever death-rates for the principal cities of the country. These data are issued in the form of bulletins, which can be obtained by writing to the Director of the Census, Washington, D.C. From the same source can also be obtained a table of the estimated populations of the principal cities for each year since the last census.

For the convenience of the reader, there is given in Appendix X a table of typhoid fever death-rates for the principal cities of the country for each year since 1898, compiled from the records of the Census Bureau and the Bureau of Labor. Comparison of these figures with those obtained from local sources do not always show an exact agreement, yet for the most part the figures may be taken as substantially correct. There is also a table giving the number of deaths in the larger cities of the country for a longer term of years, and still other tables for certain cities where the data are of especial interest.

It is common to compare death-rates by the use of

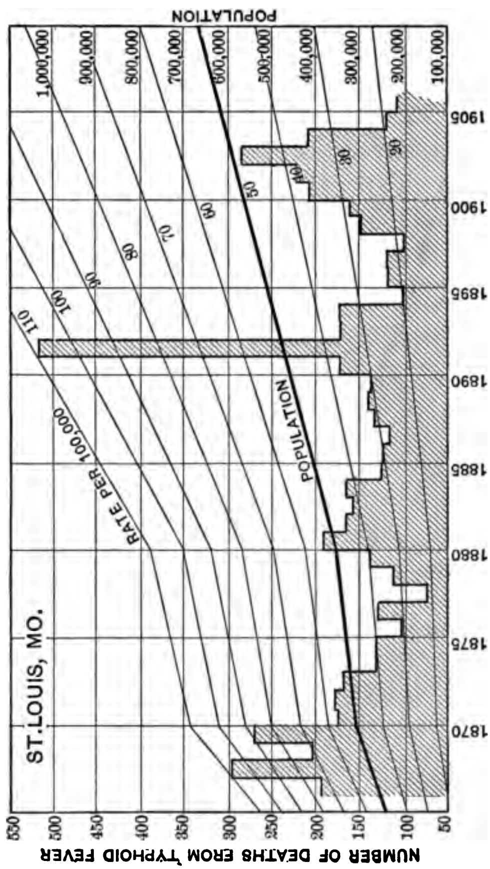


FIG. 4.

Diagram Showing the Number of Typhoid Fever Deaths and the Corresponding Death-rates in St. Louis, Mo.

diagrams. These are usually simple and self-explanatory. A very convenient form, but one little used, is shown on page 101. Here the population, the number of deaths, and the death-rate are given on the same diagram. The first two are read from the horizontal lines, the reference numbers being on the left and right of the diagrams; the third is read by using the inclined lines upon which the reference figures are marked and noting the relation of the broken profile to these lines.

CHAPTER VII.

DISTRIBUTION OF TYPHOID FEVER.

It will be of interest to consider briefly what the statistics show as to the distribution of typhoid fever among persons of different age, sex, race, occupation, etc., and the variations in the death-rates in different parts of the country. These topics cannot be discussed in detail, but the figures given are sufficient to show what are the main factors concerned in the distribution of this disease.

Age Distribution. Typhoid fever is essentially a disease of youth and middle age. Deaths from it are comparatively rare in childhood and in old age. At the time of the last United States census, in 1900, it was found that more than one-third of the deaths from typhoid fever occurred among persons between 15 and 30 years of age; only 10 per cent among children under 5 years of age, and 10 per cent among persons over 50 years of age. These are average figures, and do not hold at all times for every community. Thus, in a city where the drinking-water of a school has been contaminated, or where there has been an epidemic caused by milk, the proportion of deaths may be especially high among the children.

AGE DISTRIBUTION OF TYPHOID FEVER. FROM UNITED STATES CENSUS OF 1900.

Age in Years.	Per Cent of Population between Specified Ages.			Number of Typhoid Deaths at Each Age per 10,000 at Known Ages.			Typhoid Fever Death-rate per 100,000 Persons of Specified Age.		
	Males.	Females.	Both Sexes.	Males.	Females.	Both Sexes.	Males.	Females.	Both Sexes.
0 to 1 . . .	1.3	1.3	2.6	8.0	10.2	9.1	11	14	12
1 to 4 . . .	4.8	4.7	9.5	32.9	48.3	40.6	12	18	15
5 to 9 . . .	5.9	5.8	11.7	50.5	67.3	58.9	15	21	18
10 to 14 . . .	5.4	5.3	10.7	52.0	91.8	71.9	17	31	24
15 to 19 . . .	4.9	5.0	9.9	112.3	150.6	131.5	45	53	47
20 to 24 . . .	4.8	4.9	9.7	177.8	156.2	167.0	66	57	61
25 to 29 . . .	4.4	4.2	8.6	150.9	113.7	132.3	61	48	52
30 to 34 . . .	3.8	3.5	7.3	114.6	83.8	99.2	53	43	48
35 to 39 . . .	3.4	3.1	6.5	91.2	68.3	79.7	48	39	43
40 to 44 . . .	3.0	2.6	5.6	57.7	54.2	56.0	34	37	35
45 to 49 . . .	2.4	2.1	4.5	46.2	34.5	40.3	34	29	32
50 to 54 . . .	2.1	1.8	3.9	35.2	30.8	33.0	30	30	30
55 to 59 . . .	1.5	1.4	2.9	25.5	26.2	25.8	30	33	31
60 to 64 . . .	1.2	1.2	2.4	19.5	22.3	20.9	29	33	27
65 to 69 . . .	0.9	0.8	1.7	11.2	18.0	14.6	22	40	30
70 to 74 . . .	0.6	0.6	1.2	9.1	14.8	11.9	27	43	35
75 to 79 . . .	0.3	0.4	0.7	3.4	5.1	4.2	20	23	22
80 to 84 . . .	0.2	0.2	0.4	1.1	2.9	2.0	10	26	18
85 to 89 . . .	0.1	0.1	0.2	0.9	1.0	1.0	16	35	18
90 . . .	Less than 0.1 for all								

It is generally taken for granted that the figures which show the age distribution of typhoid fever mean that people are more susceptible to the disease in middle life than in youth or old age. This, however, is not a true explanation. A better reason would be that persons in middle life are subjected to greater exposure. In the first place it should be noted that the figures in the seventh column of the table on page 104 show a too great disparity between persons of different age, for the reason that they take no account of the age distribution of the population. It is fairer, therefore, to consider the age distribution of typhoid fever on the basis of death-rates per 100,000 persons of the specified age, as is done in the last column. From this it will be seen that the death-rate in middle life is only about twice what it is in old age, and only about three times what it is in childhood.

Age Groups.	Number of Persons Attacked.	Number of Deaths.	Percentage Fatality.	Ratio of Number of Cases to Deaths.
Under 5 years	84	2	2.38	42.0
5 to 10	154	5	3.25	30.4
10 to 15	161	13	8.07	12.4
15 to 25	281	32	11.35	8.8
25 to 35	169	26	15.38	6.5
35 to 45	91	17	18.68	5.4
45 and upwards	68	24	35.29	2.8
Total	1008	119	11.81	8.5

A study of the relative fatality of the disease at different ages also tends to show that the middle-age maximum as ordinarily stated is too much exaggerated. The percentage of children who recover from the disease is far greater than in the case of older people. This is well shown by the figures on page 105 taken from Dr. Reece's report on the epidemic which occurred in Lincoln, England, in 1905. It will be seen that in this case the fatality of the disease increased almost directly with the age.

Now, if an accurate and extended series of figures of this character could be obtained for a very large number of cases, and applied to an equally accurate and extended table showing the death-rates at different ages, it seems probable that the calculated rate per 100,000 of persons attacked at the different ages would be greatest in childhood and decrease toward old age. Unfortunately, the data for an exact calculation are not now at hand.

Fig. 5 shows diagrammatically some of these facts regarding age distribution. The lines for percentage fatality and case-rate (rate of attack) are based on inadequate data and are to be regarded merely as illustrative. A further study of this subject would prove very instructive.

The fact that so few children die of typhoid fever, then, does not show that the disease is not acquired at that age. There are doubtless many more "walking cases" among children than among adults. This helps to explain why children are such an important factor in the spread of the disease.

Infants and very young children are in general less exposed to typhoid infection than persons in middle life; their diet is much simpler, and their environment is more limited. Yet typhoid fever is by no means unknown among the very young, as the diagram shows, and physicians are coming to believe that it is more prevalent than has been generally supposed, many cases in the past having been set aside merely as infantile diarrhea, summer complaint, and other dis-

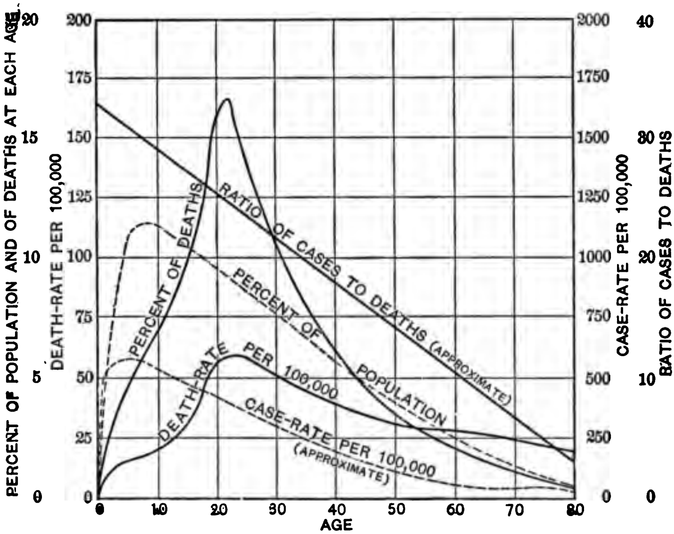


FIG. 5.

Diagram Illustrating the Age Distribution of Typhoid Fever.

eases of an indefinite character. It is at the age when young men and women come to maturity, and when they are likely to change their environment in many ways, that there is a sudden increase in the typhoid death-rate. Between the ages of 20 and 25 it reaches its highest point. It then declines gradually until about the age of fifty, after which it remains nearly constant until the age of 75, when it drops again to the same rate as that of infancy.

How much these changes are due to relative susceptibility at different ages, how much to acquired immunity and how much to environment, cannot be told. All of these factors are probably involved, but it is quite as likely that the maximum number of typhoid deaths at the age of about 25 years results from certain mathematical relations of the curves for age distribution of population, percentage fatality, and rate of attack than from any particular susceptibility at that age.

A study of age distribution in certain milk epidemics shows, as one would expect, that children are

Age in Years.	Per Cent of Typhoid Cases at Specified Age.	
	Waterville. (Epidemic Caused by Water.)	Stamford. (Outbreak Caused by Milk.)
10 to 10	17	35
10 to 20	38	24
20 to 30	26	23
30 to 40	10	12
40 to 50	4	5
50 to 70	5	1
Total	100	100

more liable to be affected than older people. The Stamford outbreak is an extreme instance of this. For comparison, the age distribution there obtained is placed beside the age distribution obtained during the epidemic at Waterville, Maine, which was due to water.

To a very great extent a person who has had typhoid fever is immune from subsequent attacks, consequently in the case of older people a substantial percentage may be considered as non-susceptible; otherwise the death-rates at the older ages would be higher than are given in the table.

Sex Distribution. Typhoid fever is more common among males than among females, as may be seen from the following figures, and from those given in the table of age distribution.

Year.	Community.	Typhoid Fever Death-rate per 100,000. Males.	Typhoid Fever Death-rate per 100,000. Females.	Percentage Excess of Death-rate Among Males.
				Per Cent.
1899	England and Wales	23.2	16.8	38
1890	U. S. Registration Area	52.4	27.4	37
1900	Do.	57.4	38.1	36
1890	U. S. Cities	40.8	28.8	41
1900	Do.	58.1	41.5	40
1900	U. S. Cities (colored population)	80.1	58.0	40
1900	U. S. Cities:			
	Under 15 years of age	21.0	23.0	−10
1900	Age 15 to 24	67.4	46.3	45
1900	Age 25 to 34	60.6	32.4	87
1900	Age 35 to 44	42.2	27.4	54
1900	Age 45 and over	35.1	24.3	44
1900	U. S. Registration Area (Rural Districts):			
	Under 15 years of age	12.9	15.9	−23
	15 to 24	47.2	37.5	26
	25 to 34	40.3	26.8	50
	35 to 44	30.8	21.3	44
	45 and over	21.8	19.7	10

The death-rate is about 35 to 40 per cent higher among males than females, but this percentage varies at different ages. Girls acquire the disease at an earlier age than boys, so that in the case of children less than 15 years old the death-rate is greater, but only slightly greater, among females than among males. As age increases, this changes until at the age of 25 or 30 years the death-rate may be 50 to 80 per cent higher among males than among females. It seems reasonable to suppose that these differences are due to differences in exposure. In childhood the difference between the environment of the two sexes is not material; but in middle life, when the activities of life are greatest, it may be supposed to be at its maximum; while in old age the environments again tend to become similar. Again, it is likely to be the case that in rural districts the environment of men and women in middle life is more nearly the same than in the case of cities; and the preceding table shows that it is in the cities that the greatest differences between the occurrence of typhoid fever in the two sexes are most marked.

Racial Distribution. The data for determining the distribution of typhoid fever among the different races are altogether too imperfect to enable any general conclusion to be drawn. The records of the last United States census show that the death-rate among the Scandinavian-born population is high, and among the Russian-born low, but such figures as these probably show the effects of environment more than the susceptibility of the races. Racial differences in diet may have some influence in the occurrence of the disease. There is some reason for thinking that a vegetable diet is less conducive to abnormal intestinal conditions than a meat diet, and it has been often remarked that the amount of typhoid fever among Italian laborers living in close quarters under poor sanitary conditions is much less than would naturally be expected. The diet of Americans, as a nation, contains a larger percentage of meat than that of European nations. This idea, however, has little or no statistical basis, and must not be too seriously considered.

As to the colored race in this country, environment seems to count for more than racial susceptibility.

In the cities of the United States in 1900 the typhoid death-rate among the male white population was 34.8 per 100,000, and among the colored population, 68.8, or about twice as much. The corresponding figures for females were 29.8 for the white population, and 70.0 for the colored. This difference is general throughout the southern states, where the colored population lives under much more unfavorable sanitary conditions than the whites. It is not so, however, among the colored people of the northern states, where the sanitary conditions of the two races are more nearly equal, — as, for instance, in the rural districts of the registration area, where in 1900 the typhoid death-rate among the white population was 25.5, and among the colored population 26.5 per 100,000.

It is interesting to note in this connection that between 1890 and 1900 the typhoid fever death-rate among the white population of American cities decreased from 49.8 to 34.8 per 100,000, or 30 per cent, while the death-rate of the colored population decreased from 70.0 to 68.8, or less than 2 per cent. In the registration area,— New York and parts of New England,— the reduction in the death-rate among the colored population was fully as great, both in the cities and in the rural districts, as among the white population. In the cities outside the registration area the death-rate among the colored population increased during the decade from 67.2 to 72.7 per 100,000, although the death-rate among the white population decreased from 61.5 to 44.6 per 100,000.

These facts all tend to show that environment rather than susceptibility is the controlling factor in the distribution of typhoid fever among the races.

Occupation Distribution. From the nature of the case, there are no general tendencies showing that typhoid fever is more closely associated with one occupation than another, except in so far as occupation is related to sex, age, local conditions, etc. Yet a study of the distribution of typhoid cases by occupation in the case of any particular locality, or at the time of an epidemic, often gives a clew to the source of the disease. In Washington, D.C., during the summer of 1906 (June 11–Nov. 1), the morbidity rate among school children was 500 per 100,000, and this included 27 per cent of all the cases; while among very young children the morbidity rate was 185; among housewives, 223; servants, 212; laborers, 259; clerks, 193, etc. A high morbidity rate among children suggests the probability of milk infection.

Rural and Urban Distribution. Contrary to what many people suppose, typhoid fever is more largely a rural disease than an urban disease, meaning by rural small communities in distinction from large communities. In cities, great epidemics occur at intervals; but in the small settlements of the country, the disease is present year after year, with here a victim and there a victim, and this inconspicuous but constant succession of cases counts far more than the spectacular epidemics which startle the readers of our daily papers. Dr. John S. Fulton, in 1903, presented to the American Medical Association some striking figures illustrating this relation between urban and rural typhoid, which may be summarized as follows:

	Average Per Cent of Rural Population.	Average Typhoid Fever Death-rate per 100,000.
Five states in which the urban population was more than 60% of the total	30	25
Six states in which the urban population was between 40% and 60%	49	42
Seven states in which the urban population was between 30% and 40%	67	38
Eight states in which the urban population was between 20% and 30%	75	46
Twelve states in which the urban population was between 10% and 20%	87	62
Twelve states in which the urban population was between 0 and 10%	95	67

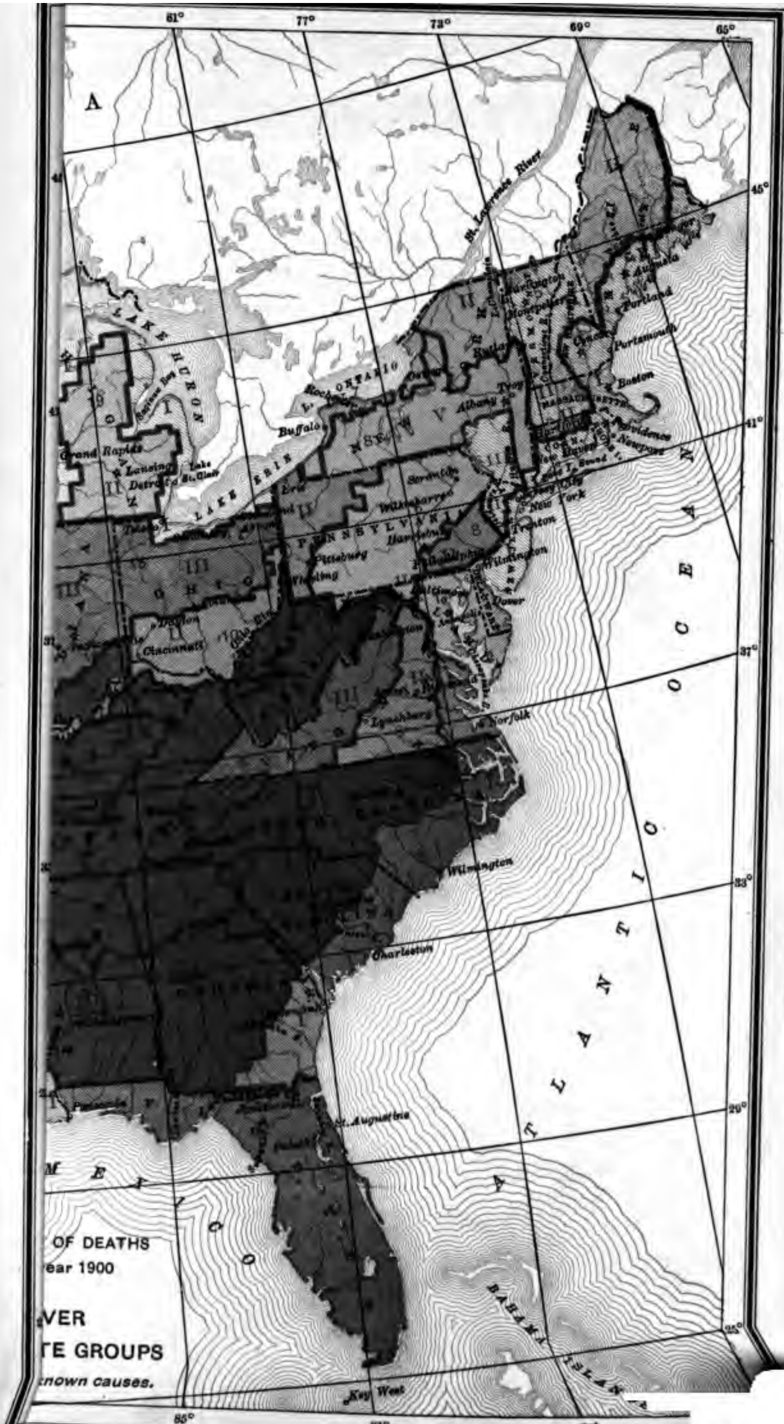
Comparisons made between the city and country districts of the different states show the same relation, although in some years exceptions to the rule may be found. The figures given under climatic distribution sufficiently illustrate this point.

The subject of rural typhoid fever needs far more attention than has ever been given to it, especially in the southern states. The smaller communities have not done their duty in stamping out the disease. It has been said that it is easier to save dollars than to save dimes; in the same way it is easier to reduce the typhoid fever death-rate of a great city by building filters and sewerage works than to give attention to the thousand foci of infection scattered through the villages of New England, the plantations of the South, and the lumber camps of the Northwest.

Climatic Distribution. Typhoid fever is more abundant in warm climates than in cold climates; but to what extent this is due to the effect of temperature, and what to the nature of the environment, it is difficult to say. There is reason to believe that the latter is the more important factor.

In the United States typhoid fever increases considerably from north to south. If the Atlantic coast and Gulf coast regions are followed from Maine to Texas, this increase is very evident, as the following census figures show:

Region.	Per Cent which the Typhoid Deaths in 1900 were of the Total Deaths.	
	Rural.	Cities.
North Atlantic Coast Region	1.17	1.29
Middle Atlantic Coast Region	2.54	1.15
South Atlantic Coast Region	4.95	2.31
Gulf Coast Region	6.16	2.38



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A
St. Lawrence River
LAKE HURON
LAKE ERIE
ONTARIO
ATLANTIC OCEAN
MEXICO
BAHAMA ISLANDS
Grand Rapids
Lansing
Detroit
Toledo
Buffalo
Rochester
Albany
Troy
Burlington
Montpelier
Rutland
Portland
Augusta
Concord
Portsmouth
Boston
Providence
Newport
New York
Trenton
Scranton
Wilkesbarre
Harrisburg
Philadelphia
Wilmington
Pittsburg
Wheeling
Dover
Dayton
Cincinnati
Norfolk
Lynchburg
Wilmington
Charleston
St. Augustine
Pensacola
Key West
PENNSYLVANIA
OHIO

It will be noticed that the increase in the rural districts is considerably greater than in the cities, — presumably because the general sanitary conditions, the quality of the drinking-water, etc., are better in the cities than in the country, especially in the South.

If a line be taken down the hilly and mountainous regions in the general direction of the Appalachian Mountains, or down through the middle West, the same distribution will be seen.

Region.	Per Cent which the Typhoid Deaths in 1900 were of the Total Deaths.	
	Rural.	Cities.
Northern Hills and Plateaus	1.81	1.81
Central Appalachian	2.57	1.92
Southern Appalachian	6.45	4.16
Southern Interior Plateaus	7.61	...
Heavily Timbered Region of the Northwest	2.15	3.10
Prairie Region	3.59	3.35
Southwest Central	7.06	3.87

There are some exceptions to this regular increase of typhoid fever southward. For example, in 1900 the death-rate was higher in certain parts of the state of Washington than in Florida. The city of Winnipeg, Manitoba, has a high death-rate, and the rates in many other parts of Canada are high.

Geographical Distribution. Typhoid fever is much more abundant in the United States than in most foreign countries. This is shown by the following data, taken from the Mortality Statistics of the Bureau of the Census for 1905.

Date.	Country.	Typhoid Death-rate per 100,000.
1900	United States	47.3
1900	United States, Registration Area	33.8
1900–1904	United States, Registration Area	33.7
"	Norway	6.2
"	Switzerland	6.5
"	Germany	8.5
1902	Holland	8.6
1900–1904	Sweden	12.2
"	Scotland	12.7
"	England and Wales	12.9
"	Ireland	14.2
"	Belgium	20.2
"	Hungary	28.3
"	Italy	37.8
1902	Spain	45.8

The following figures show the typhoid death-rates in various European cities about the year 1903: —

	Typhoid Death-rate per 100,000.
Berlin, Germany	5.0
Vienna, Austria	5.1
Hague, Holland	5.1
Berne, Switzerland	7.0
Copenhagen, Denmark	13.3
London, England	14.4
Brussels, Belgium	17.2
Paris, France	21.7
Lisbon, Portugal	29.4
Madrid, Spain	50.0
St. Petersburg, Russia	80.7

The question naturally arises, "Why is the typhoid death-rate so much lower in Western Europe than in the United States?" There are many reasons for it. Surface waters used without filtration are less frequent abroad. In Germany, for instance, the filtration of surface waters is required by law, and rigid restrictions are in force as to the efficiency necessary to be obtained by the filters. Probably, too, less water is used there as a beverage. In Europe, milk is more often boiled before using, and oysters are not as much eaten as with us. Better water and safer milk having materially reduced the disease, the secondary causes, such as contagion and carriage by flies, decrease as a matter of course. It is possible that differences in the classification of disease and incompleteness of records may influence the figures given above, but they do not materially affect the comparison.

A generation ago the waters of Northern Europe were far less safe than they are to-day, and there was then good reason for travelers refraining from drinking the public supplies, just as there is to-day in Southern Europe and in the Orient. The movement for obtaining pure water-supplies is, however, world-wide, and at the present time the average water-supplies in England and in Northern Europe are quite as safe to drink as the average supplies of America.

In Japan the water-supplies of most of the large cities have been subjected to filtration for a number of years.

It is said that typhoid fever is an infrequent disease in the Philippine Islands, and that it was practically unknown before the time of the American occupation, thus illustrating Professor Sedgwick's statement that typhoid fever is a disease of civilization. Since then, to quote from a report to the Philippine Commission, "the disease has made its appearance from time to time in various parts of the islands, especially at places at which troops were stationed." At Baguio it was said that the near approach of the new road, with its swarms of workmen and its attendant swarms of flies, led to the temporary introduction of several diseases which had not been previously present. There was a slight epidemic of typhoid fever, which was spread by flies, but which was promptly controlled with a total of only seven cases.

In the city of Manila itself typhoid fever has been by no means absent, as the following figures show. During the year ending Sept. 1, 1905, there were 122 deaths, and during the following year, 45. During the year ending June 30, 1905, there were 23 cases and 5 deaths among the United States troops.

MANILA, PHILIPPINE ISLANDS, SEPT. 1, 1904, TO SEPT. 1, 1905.

Race.	Population (1903).	Deaths from All Causes.	Death-rate per 1000. All Causes.	Typhoid Fever Deaths.	Typhoid Death-rate per 100,000.
Americans . . .	4,389	39	8.88	1	25.6
Philippinos . .	189,782	8,453	44.54	110	58.2
Spaniards . . .	2,528	51	20.17	} 6	} 160.5
Other Europeans	1,117	14	12.53		
Chinese	21,230	343	16.15	5	23.6
All others . . .	...	26	29.05	...	...
Total . . .	219,941	8,926	40.58	122	55.7

Apparently these figures overstate the amount of typhoid present, for recent studies carried on in the government laboratory have shown that a large proportion of the so-called typhoid fever cases fail to respond to the Widal test.

In one of the surgeon's reports to the Commission it is stated that "with the rapid increase in the use of milk in the city of Manila and because of the thickly populated watershed from which the city obtains its water-supply, it is rather probable that Manila is in considerable danger of becoming thoroughly infected with typhoid fever unless the greatest precautions are taken to prevent its gaining a foothold."

During 1898–1902 the average death-rate for typhoid fever in various cities of the West Indies and South America were as follows: —

	Rate per 100,000.
Havana, Cuba	39.3
San José, Costa Rica	74.9
Santiago de Chile	48.3
Rio Janeiro	15.9
Buenos Aires	22.0

Geological Distribution. Studies of the distribution of typhoid fever along east and west lines of the United States do not reveal any changes that can be attributed to altitude, to rainfall, or to any geographical or climatic influence. There does seem to be, however, some coincidence of high typhoid fever rates and the presence of a clayey soil. Within the area of the glacial drift, and along the eastern sea-coast, the disease is somewhat less abundant than in the alluvial regions of the southern and central states. This area is so largely coincident with the presence of the negro race, however, that no sweeping generalization can be made; yet it is evident that with an impervious soil, the opportunities for surface contamination of streams, springs, and wells are greater than in a sandy region where the natural purification of the soil plays a larger part. The soil factor must not be given too much weight, however; for it is to be remembered that in England, where the soil is heavy, the typhoid rate is comparatively low.

The opportunities for the pollution of wells are somewhat increased in a limestone region, where cracks and crevices in the rocks may exist, but this factor does not manifest itself in looking at the distribution of the disease over large areas.

Hydrographic Distribution. Typhoid fever is often abundant along the courses of streams, especially where the streams are used both for the disposal of sewage and for the supply of drinking-water to the cities along the shores. Examples of this condition along the Penobscot River, the Merrimac, the Hudson, and other streams are referred to elsewhere.

It is said that all through the Potomac and Shenandoah valleys typhoid fever has been constantly prevalent ever since the Civil War, and no doubt much of the typhoid fever in the South to-day represents a legacy left by the armies engaged in that conflict.

The disease is sometimes abundant at sea beaches and along the shores of bodies of water into which sewage is discharged. Epidemics of some magnitude have resulted from bathing in infected waters; and it has been suggested that along water-fronts where sewage is discharged under the wharves, flies may act as carriers of the bacilli

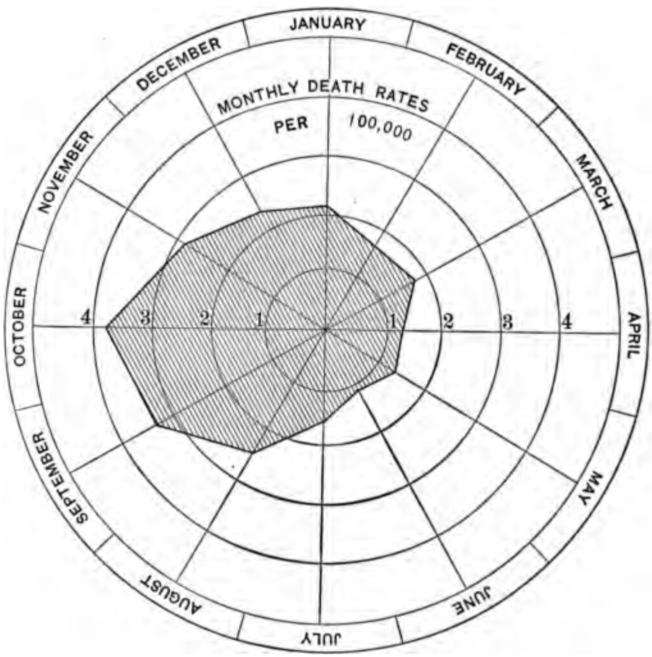


FIG. 7.
Diagram Showing the Seasonal Distribution of Typhoid Fever in the United States. (From the U. S. Census Bureau of 1900.)

from the deposits left by the tides to persons dwelling or working near the shores. Mr. D. D. Jackson in a report to the Merchants' Association has recently emphasized the importance of this factor in New York City.

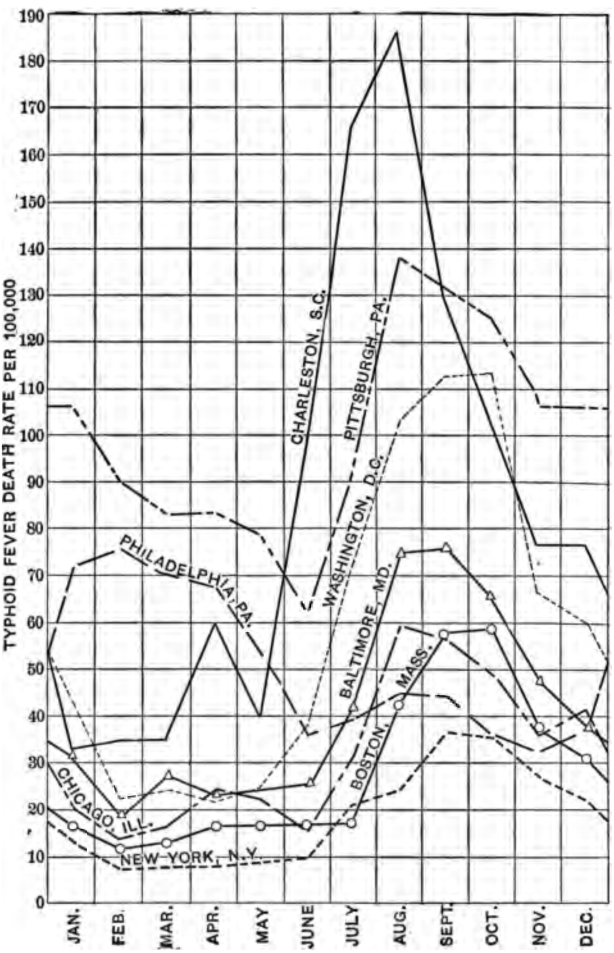


FIG. 8.

Diagram Showing the Seasonal Distribution of Typhoid Fever in Certain Cities of the United States.

Seasonal Distribution. In the United States the normal seasonal distribution of typhoid fever is shown by Fig. 7. June is the month when the disease is usually least abundant. During the summer, it increases gradually until it attains a maximum in October, then

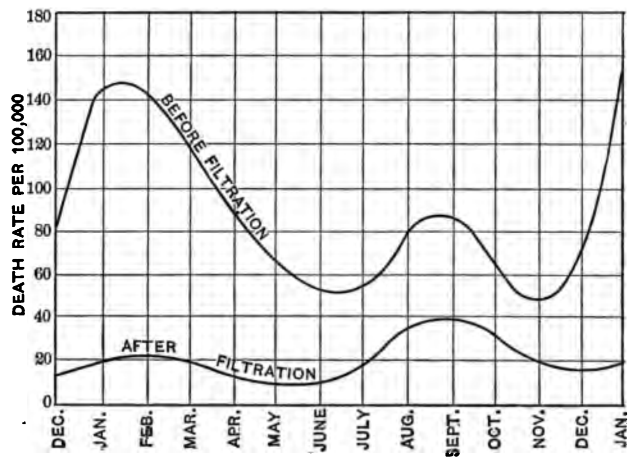


FIG. 9.

Diagram Showing the Seasonal Distribution of Typhoid Fever in Albany, N. Y., before and after the Filtration of the Public Water-Supply.

it gradually decreases, though with some slight fluctuations during the winter and spring months.

This normal curve holds approximately for most rural sections and for cities which are provided with good, or fairly good, water-supplies. Thus the seasonal distribution of typhoid fever in New York City follows the normal curve. In cities which have polluted water-supplies there is likely to be a more irregular occurrence of the disease, with maxima, or sub-maxima, in the colder part of the year. The occurrence of an epidemic is likely to abnormally affect the shape of the

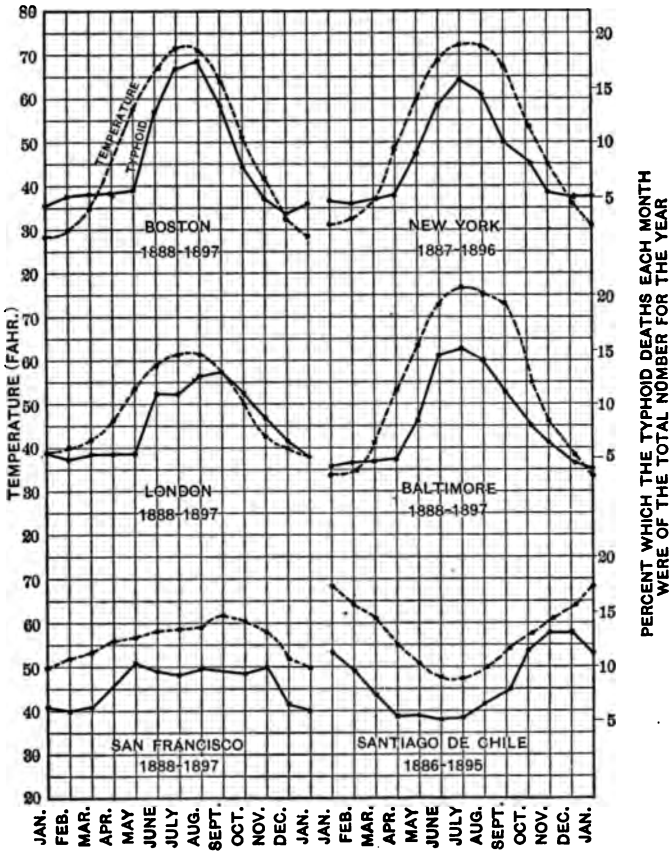


FIG. 10.

Diagram Showing the Relation between Atmospheric Temperature and Seasonal Distribution of Typhoid Fever. (After Sedgwick and Winslow.)

curve. The diagram on page 122 shows the seasonal distribution of the disease in cities where the public water-supply is of fairly good sanitary quality, and in cities where it is polluted.

It will be seen from these curves that the character of the water-supplies is best indicated by the typhoid fever records during the winter and spring months. Of the three largest cities, New York has the best water, Chicago next, and Philadelphia next; and this is the order of the typhoid curves during the first half of the year. Not so, during the summer and autumn. Here the differences between the three are much less, and the rate at Chicago is highest. There is reason to believe that during this season of the year the effect of the quality of the milk-supply, and the influences of flies and general sanitation, exert a preponderating influence on the height of the curve.

Even more striking, perhaps, is the change in the seasonal distribution of typhoid fever after a city has changed its source of water-supply from bad to good, or has improved the character of its supply by filtration. Albany is a good illustration of this.

Many theories have been advanced to account for the greater general prevalence of typhoid fever in the autumn than at other seasons of the year. That it is in some way related to temperature can scarcely be questioned. Sedgwick and Winslow have illustrated this by a beautiful series of diagrams for various cities in different parts of the world. Some of these are reproduced in Fig. 10.

The way in which the typhoid curves follow the temperature curves is very striking. In order to better show the correspondence, the typhoid fever curves have been set back two months, — thus allowing for the period elapsing between the date of infection and the date of death. Sedgwick and Winslow explain this correspondence between temperature and typhoid by the general unfavorable influence which cold exerts on the persistence of the typhoid bacillus outside the body. It is held that during warm weather transmission by contact is more frequent, and infection by other methods rendered more likely by reason of an increased longevity of the bacilli.

Other reasons for the greater prevalence of typhoid fever in warm weather will naturally suggest themselves. Flies and other insects are more abundant and more active in summer; bacteria multiply faster in milk; fruits, berries, and uncooked foods are more commonly used; more water is drunk, and ice is put into it; wells are lower, and the danger of contamination is thereby increased; traveling is more common, and opportunities for transmission by contagion are thus greater. The consumption of oysters, on the other hand, is less in summer than in winter. The idea has been recently suggested by a number of sanitarians, that the greater prevalence of diarrheal diseases of a mild type and of various intestinal disorders during the hot weather, due to bad milk, unripe fruit, etc., may act as exciting causes, and, by reducing a person's vitality and by irritating the intestinal walls, may increase the chance of infection among those who are exposed. The somewhat greater proportion of typhoid cases among young people during the summer than during the winter lends countenance to this theory, as well as the fact that typhoid epidemics are quite frequently preceded or accompanied by an unusual amount of diarrhea. On the other hand, the testimony of the commission that studied the occurrence of typhoid fever in our army during the Spanish War is to the contrary.

Vacation Typhoid. The autumnal increase of typhoid fever in cities is sometimes referred to as "vacation typhoid," — the idea being that it is due to patients returning sick from the country. This theory is based on the fact that typhoid fever is at present chiefly a rural disease, and so far as this goes it is correct. But the notion of "vacation typhoid" has been very much overworked, and, as a matter of fact, it does not to any very material extent account for the summer and autumnal increase of typhoid fever in the large cities. In Washington it was estimated that during the summer and autumn of 1906, 85 per cent of the cases were contracted within the city, and studies of imported cases in other cities have given similar figures.

Cities which have polluted water-supplies generally show this fact by an unusual prevalence of typhoid fever at other seasons than the summer and autumn, and most of the severe epidemics due to infected water have occurred during the late autumn, winter, or spring; but in the cases of cities supplied with water from impounding reservoirs located on watersheds more or less polluted, opportunities for the transmission of infection may be increased during the late summer. The reservoirs are then likely to be drawn down, so that a hard rain may carry infection rapidly through them to the city. It seems to be a fact that in such cities the amount of typhoid fever is greater during years of dry summers.

Chronological Distribution. Typhoid fever is gradually becoming less frequent as a cause of death. This is due partly to a reduction in fatality through better medical treatment, but is chiefly due to a reduction of infection by reason of better water-supplies and a more logical sanitary régime based on the germ theory of disease. The chronological distribution of the disease will be repeatedly referred to in other places, but at this point it may be sufficiently illustrated by the following average figures for twelve states, including all the New England states and New York and New Jersey, Maryland, California, Minnesota, and Michigan.

Year.	Average Typhoid Fever Death-rate per 100,000.	Year.	Average Typhoid Fever Death-rate per 100,000.
1880	55	1895	28
1885	46	1900	23
1890	36	1905	21

A generation ago, about one person in every five or six in the United States was bound to have the typhoid fever at some time in his life, and one person in every fifteen or twenty died in an uphill fight against this insidious enemy. To-day, under the average conditions in the United States, the chance of having the typhoid fever at some time between the cradle and the grave is only about one in ten. What is the future to be? The prospect is bright. The indications are that the disease is soon to become much less prevalent than it is to-day. In another generation the death-rate ought not to be over a third or a quarter of what it now is, — and who can say that the disease will not be all but obliterated, just as smallpox has almost vanished from our midst?

Typhoid fever has been decreasing in foreign countries. The following figures show this decrease for England and Wales:

Year.	Typhoid Death-rate per 100,000.	Year.	Typhoid Death-rate per 100,000.
1870	38	1890	17
1875	37	1895	17
1880	26	1900	17
1885	17	1905	9

Effect of Spanish War. The Spanish War caused something of a set-back to the gradual decrease of typhoid fever in America. The enormous number of cases that

TABLE SHOWING THE TYPHOID FEVER DEATH-RATE FOR NINE STATES.

Year.	Death-rate per 100,000.	Year.	Death-rate per 100,000.
1895	30.5	1899	23.5
1896	27.7	1900	27.9
1897	21.5	1901	25.2
1898	25.2	1902	20.2

occurred in the military camps caused the disease to be quite generally scattered through the country, and these new foci gave rise to various outbreaks, with the result that the general death-rate temporarily increased. Mention is made elsewhere of the fact that in New York City and in Brooklyn the typhoid fever rate in 1898 increased

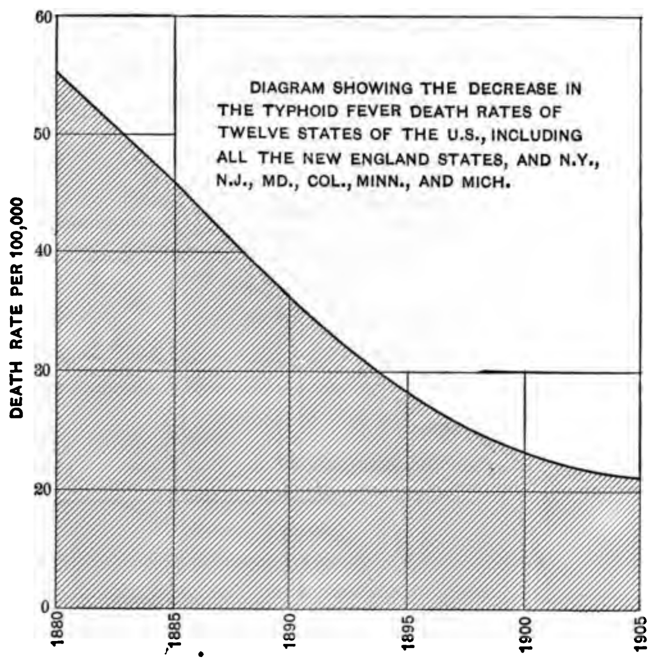


FIG. 11.

on account of the soldiers returning from the war. A similar increase occurred in many other cities; for instance, in Portland, Maine, the death-rate rose from 24 to 76 per 100,000. Statistics collected for nine states showed a decided increase during the same year. For instance, the average death-rate had been 21.5 in 1897, but rose to 25.2 in 1898, falling again to 23.5 in 1899.

The amount of typhoid fever in 1899 was unexpectedly low, but in 1900 it again rose, and was even higher than in 1898. Whether or not this increase was due to the spread of infectious matter by the soldiers, cannot be said. It may have been; but if this were so the question comes, Why was not the rate high in 1899? Since 1900 there has been a general reduction in the prevalence of typhoid fever, but 1904 was another bad year. During this year the great epidemics occurred in Ithaca, Butler, and elsewhere. There are no data for explaining these waves of typhoid which sometimes sweep over the country.

Distribution by Causes. To state, with any degree of exactness, the proportion of cases of typhoid fever due to different causes, is absolutely impossible from such data as now exist, and yet this is a question often asked. Even if the data were at hand, it could be answered only in a very general way, for the relative effects of different causes are not the same at all times and in all places. From a study of the statistics, however, a rough approximation can be made of the more important causes, though the results are hardly more valuable than a shrewd guess.

When a contaminated public water-supply is suddenly improved in quality by the installation of a filter plant, there is nearly always a decided fall in the typhoid fever death-rate. Cities which have pure water have a generally lower death-rate than those which have an impure supply. These differences may serve as a rough measure of the amount of typhoid fever due to impure public water-supplies. The average typhoid death-rate in American cities is about 35 per 100,000. The cities in the north which have safe water-supplies have lower rates, — usually as low as 20, and frequently as low as 15 or even 10. Taking the country over, perhaps 20 may be taken as an average figure. The difference between 20 and 35 may be considered, therefore, as being due to infected public water-supplies. Of the "residual typhoid," the most potent causes are probably infected milk, and direct infection by contagion, by flies, etc. Oysters, vegetables, and other foods really play a very insignificant part in the general typhoid death-rate.

A number of years ago infected water probably caused more typhoid fever than all the other causes combined. That is not the case to-day when the country as a whole is considered, although it is still the most important cause, and in some cities, as in Pittsburgh and Philadelphia, it still overshadows all other causes. The long-continued struggle for pure water is bearing fruit, and to-day in many American cities, and even in entire states, where the public water-supplies are well guarded from pollution, infection by water has come to be a secondary cause of the disease.

In a general sort of way it may be said that in the cities of the United States, at the present time, about 40 per cent of the typhoid fever is due to water, 25 per cent to milk, 30 per cent to ordinary contagion (including fly transmission), and only about 5 per cent to all other causes. In cities supplied with pure well water or filtered water, the effect of water is negligible; where the water is impure, it is still the most important cause of the disease. In the case of rural districts there are no data to show the relative effect of infected wells, infected milk, and direct infection, but, in all probability, the "honors are about even."

While the care of water-supplies cannot be in any degree relaxed, efforts for further reducing the disease must be directed to causes other than water. It is the realization of this fact that explains in part the present strenuous struggle which is being made in our large cities to improve the milk-supply. In many ways the milk problem is more difficult than the water problem, as the sources of supply are so numerous, the commodity is such a delicate one to handle, and its distribution so complicated. When one considers the difficulties of the milk situation, and the large percentage of the disease due to personal contact, that is to contagion, the wisdom of stamping out the disease at the bedside must be evident to every one.

CHAPTER VIII.

TYPHOID FEVER EPIDEMICS.

FROM time to time, in one place or another, typhoid fever suddenly increases until it is said to be epidemic. If the increase is confined to a small portion of the community and is more or less localized, it is usually termed a "local outbreak," or a "sporadic outbreak;" but if it is widely spread and can be attributed to some general cause, as the water-supply, or the supply of some large milk dealer, it may be fairly termed an epidemic. There is no necessity, however, for drawing a fine distinction between the two, as the difference is merely one of magnitude; but it will often be wise to use the term "outbreak" rather than "epidemic," in order to prevent undue excitement and avoid the opprobrium attached to the larger word.

A study of typhoid fever epidemics forms a necessary part of the history of our subject, and from them many lessons in sanitary science may be learned. It will be instructive to consider in some detail a few of the more important epidemics of typhoid fever which have been traced to different causes. Those chosen for illustration have been selected either by reason of their magnitude, or because they illustrate some new or interesting case of infection. The data given are taken from well-known authorities, and references to more detailed accounts are given in the appendix.

Classification of Epidemics. The epidemics and outbreaks of typhoid fever to be described may be classified according to their suspected causes as follows:

I. Epidemics due to infected water:

1. Epidemics caused by the sudden infection of a water-supply popularly supposed to be of good quality.
   - Plymouth, Pa.
   - New Haven, Conn.
   - Ithaca, N. J.
   - Scranton, Pa.
2. Epidemics caused by water constantly subject to contamination.
   - *a.* River water.
     - Lowell and Lawrence, Mass.
     - Waterville and Augusta, Maine.
     - Pittsburgh and Allegheny, Pa.
   - *b.* Lake water.
     - Chicago, Ill.
     - Cleveland, Ohio.
     - Burlington, Vt.
3. Epidemics caused by water accidentally infected.
   - Butler, Pa.
   - Lowell, Mass.
   - Millinocket, Maine.
   - Baraboo, Wis.
   - Steamer "Northwest."
4. Epidemics and outbreaks caused by infected ground water.
   - Lausen, Switzerland.
   - Basingstoke, England.
   - Newport, R.I.
   - Auxerre, France.
   - Trenton, N.J.
   - Mount Savage, Md.

II. Epidemics and outbreaks due to contagion, flies, and general uncleanliness:

- New Haven County Jail.
- Winnipeg, Manitoba.
- United States Military Camps during the Spanish War.

III. Outbreaks due to infected milk:
Somerville, Mass.
Springfield, Mass.
Stamford, Conn.
Marlborough, Mass.
Waterbury, Conn.
Montclair, N.J.

IV. Outbreaks due to infected oysters and other shell-fish:
Wesleyan University, Middletown, Conn.
Winchester-Southampton, England.
Lawrence, Long Island.

V. Outbreaks due to infected fruit and vegetables:
Springfield (1905).

VI. Outbreaks due to infected ice:
Ogdensburg, N.Y.

VII. Outbreaks due to other causes, such as cream, ice-cream, various foods:
No specific examples described.

Epidemics Due to Infected Water.

The Plymouth Epidemic. Among the typhoid fever epidemics which have occurred in America that at Plymouth, Pa., deserves first mention, partly for the reason that it was one of the first large epidemics where the cause was definitely ascertained, and partly because of the influence which the lessons taught by it have had on sanitary science in this country.

The epidemic occurred in the spring of 1885. Plymouth at that time was a mining town of about 8000 inhabitants. It had a public water-supply derived from a stream which drained an almost uninhabited watershed, and the water was stored in a series of four small reservoirs. The highest of these reservoirs had a capacity of 5,000,000 gallons; the next, 3,000,000; the next, 1,700,000; and the lowest, nearest the city and used as a distributing reservoir, 300,000 gallons. This water-supply, though apparently satisfactory in quality, was not sufficient at all times for the needs of the city, and occasionally it was necessary to supplement it by pumping from the Susquehanna River. Well waters were also used by some of the inhabitants. As it turned out, neither the well water nor the polluted Susquehanna water played any part in the epidemic, which, through the efforts of Dr. L. H. Taylor of Wilkesbarre, and others, was found to have been caused by the "pure mountain stream" supply of the Plymouth Water Company.

It is unnecessary to follow here all the steps by which the epidemic was traced to its origin; it will be simpler to recite the pertinent events chronologically, and this will also indicate more clearly the relation between cause and effect.

In an open clearing near the banks of the stream and just below the upper reservoir, there existed one of the few houses on the watershed. The man who occupied this house went to Philadelphia on Dec. 24, 1884, and on Jan. 2, 1885, returned home ill with typhoid fever. It was a severe case. The patient was in bed for many weeks. By the first of March he was convalescent, but a relapse occurred, and it was the middle of April before the physician's visits were discontinued. "During the course of his illness, his night dejecta were thrown without disinfection upon the snow and frozen ground, toward and within a few feet of the edge of the high bank which sloped precipitously down to the stream supplying the town with water." "The dejecta passed during the day were emptied into a privy a little farther back, the contents of which laid almost upon the surface of the ground, so that at the first thaw or rain they too would pass down the sloping bank and into the stream."

Until the latter part of March the ground remained frozen and covered with snow, and under these conditions it is improbable that the dejecta reached the water of the stream. But during the last week in March there was a thaw, the air temperature increased rapidly until, on April 4, the maximum was 70 degrees. During these few days of warm weather the accumulated dejecta of many weeks probably found their way into the stream which supplied the town with water.

On the evening of March 26, the superintendent of the water company visited the reservoirs and found that the two lower ones were almost empty, while the one just below the house where the typhoid patient lived, was filling rapidly. He found, however, that the short pipe which allowed the water to discharge from the bottom of this reservoir into the stream leading to the reservoir below it was frozen, and he caused a fire to be built to melt the ice in the pipe. This done, the water flowed from the bottom of this reservoir down through the two reservoirs below it, and thence into the town, where in all probability it first arrived some time between March 28 and April 4 or 5, — that is, from two days to a week after it was let down from the third reservoir.

The first case of typhoid fever in the town occurred on April 9, and from this time on the disease spread rapidly. During the week beginning April 12, from

50 to 100 new cases appeared daily, and it is said that on one day 200 new cases were reported. All classes of people were attacked in all parts of the town, until, before the epidemic ceased, out of the 8000 inhabitants, 1104 contracted the disease, and 114 died.

This epidemic, as Dr. Taylor said in his report, "was one of the most remarkable ones in the history of typhoid fever, and taught important lessons, though at a fearful cost. One is, that in any case of typhoid fever, no matter how mild, or how far removed from the haunts of men, the greatest possible care should be exercised in thoroughly disinfecting the poisonous stools. The origin of all this sorrow and desolation occurred miles away on the mountain side, far removed from the populous town, and in a solitary house situated upon the banks of a swift-running stream. The attending physician did not know that this stream supplied the reservoirs with drinking-water. Here, if at any place, it might seem excusable to take less than ordinary precautions; but the sequel shows that in every case the most rigid attention to detail in destroying these poisonous germs should be enjoined upon nurses and others in charge of typhoid fever patients, while the history of this epidemic will but add another to the list of such histories which should serve to impress medical men, at least, with the great necessity for perfect cleanliness, — a lesson which mankind at large is slow to learn."

The epidemic is interesting to bacteriologists from the fact that it throws some light upon the ability of the typhoid bacillus to survive the apparently unfavorable conditions of winter. Some of the bacilli at least must have lived and retained their virulence in the frozen fecal matter for many weeks.

The New Haven Epidemic. In the early spring of 1901 an epidemic of typhoid fever occurred in New Haven, Conn., which was similar in many ways to that which occurred in Plymouth in 1885. During April, May, and June, 514 cases occurred, resulting in 73 deaths. The epidemic began about the middle of March, and increased as shown by the following figures:

Period.	Number of Cases.	Period.	Number of Cases.
March 20–26, 1901 . .	36	April 11–15, 1901 . .	38
March 27–31, 1901 . .	99	April 16–20, 1901 . .	9
April 1–5, 1901 . . .	195	April 21–25, 1901 . .	3
April 6–10, 1901 . . .	58	April 26–30, 1901 . .	3

Professor Herbert E. Smith made a careful study of this epidemic, and found that it was unquestionably due to an infection of one of their sources of public water-supply.

The water-supply of New Haven was drawn from five distinct systems. It was all surface water, and was used without filtration. One of these sources was known as the Dawson supply. Dawson Lake was a storage reservoir located on West River in Woodbridge, five miles from the city. It had an area of 60 acres, and a capacity of 300,000,000 gallons. The watershed tributary to the lake had an area of 13.6 square miles, upon which there was no direct sewage pollution, while the rural population amounted to only 25 per square mile.

A mile and a half above the Dawson dam a small stream flowed into the river, and about half a mile up this stream there was a farmhouse situated at an elevation of about 180 feet above the water in the lake.

During January and February, 1901, several cases of typhoid fever occurred in this house. The excreta were thrown into a shallow privy vault without disinfection (for the reason that typhoid fever was not at first recognized), where they must have accumulated and remained more or less frozen for six weeks or more. This privy was 325 feet from the brook and 40 feet above it. During February and the first part of March, the weather was steadily cold; but on March 10 and 11 there was a heavy rainfall, during which the precipitation was 2.46 inches. The flow was so large that in spite of the intervention of the storage reservoir, the water in the city was in a turbid condition on the afternoon of March 11. As the typhoid fever outbreak began about ten days later, there seems to be little doubt that the infection took place at this time.

Professor Smith found that 96 per cent of the cases that occurred were in the district supplied with water from Dawson Lake.

In the course of his studies he made some interesting comparisons of the distribution of the cases by ages, which were in striking contrast to those found in the Stamford epidemic of 1895, which was attributed to infected milk. The following table shows these percentages.

PER CENTS WHICH THE NUMBERS OF CASES AT CERTAIN AGES WERE OF THE TOTAL NUMBER OF CASES.

Ages.	0–5.	6–15.	16–30.	31–45.	Over 45.
	%	%	%	%	%
Stamford Epidemic	16.95	48.19	32.90	14.76	4.15
New Haven Epidemic . .	8.10	36.73	49.66	10.43	3.18

The Ithaca Epidemic. In the winter of 1903, Ithaca, N.Y., the seat of Cornell University, was visited by a severe epidemic, in the course of which 1350 cases of typhoid fever occurred, in a population of about 13,156. More than 500 homes were visited, and there were 82 deaths. The epidemic covered a period of about three months, and extended from about the 11th of January, 1903, to the first of April, although for several months before the epidemic began, typhoid fever had been unduly prevalent. This epidemic was carefully studied by Dr. George A. Soper, in the interest of the New York State Department of Health.

The original case, or cases, which gave rise to the epidemic were not ascertained, but that the disease was due to the public water-supply was made certain by the investigations carried on.

Ithaca had at that time three separate sources of water-supply, two of these being owned by the Ithaca Water Company, and the third by Cornell University. The latter supply, however, probably had little or nothing to do with the epidemic.

Of the other two supplies, the larger one was derived from Six-mile Creek, which had a drainage area of about 46 square miles. The water was taken from a small reservoir formed by damming this stream below the intake crib, and pumped into a reservoir and standpipe, from whence it flowed by gravity to the consumers. The second supply was taken from Buttermilk Creek, a stream which drained about 12 square miles.

The conditions on the two streams were similar. On both the run-off was rapid, and the flow was subject to violent fluctuations. The river beds were deeply eroded through the soil, and at times of flood the water carried a large amount of silt in suspension. Both streams were considerably polluted. On the drainage area of Six-mile Creek there dwelt a population of more than 2000, about forty per cent of which lived in villages bordering on the creek. The nearest of these villages to the waterworks was Brookton, five miles above the intake. The inspection of the watershed showed that there were numerous sources of contamination, and that even in the city of Ithaca, a few rods above the intake of the waterworks, there were no less than seventeen privies located on the precipitous banks of the creek. It is known, furthermore, that during the year previous to the epidemic, there had been at least six cases of typhoid fever on the watershed.

At the time of the epidemic, a new dam was being constructed on Six-mile Creek, a short distance above the water works intake. One theory advanced was that the excreta from a possible case of typhoid fever among these laborers may have caused the epidemic. No proof of the existence of such a case, however, was found. Another possible source was a gang of laborers working near the stream three miles above the intake, where one of the party was known to have had the disease. Whether some one of these cases or some unknown case was the active agent in causing the epidemic was not determined, but that the water was in some way infected cannot be doubted.

As in the cases of Plymouth and New Haven, the typhoid epidemic in Ithaca followed a flood in the river. During the month of December, 1902, the precipitation had been unusually heavy. General rains occurred between the 19th and 22d, and there were heavy rainfalls on the 13th, 16th, and 21st.

The epidemic began about the 11th of January, and gradually increased in severity during the rest of the month. On some days more than 30 new cases were reported. The following figures show the progress of the epidemic by weeks:

Week Ending —	New Cases Reported by the Physicians.[1]	Week Ending —	New Cases Reported by the Physicians.[1]
January 17, 1902	21	February 28, 1902	59
January 24, 1902	54	March 7, 1902	31
January 31, 1902	105	March 14, 1902	18
February 7, 1902	170	March 21, 1902	3
February 14, 1902	137	March 28, 1902	3
February 21, 1902	102		

[1] The actual number of cases was larger than these figures would indicate, as not all were reported.

This epidemic occasioned an unusual amount of interest by reason of the fact that the town included about 3000 students in Cornell University. Hundreds of the students left town, some of them ill with the disease. Some of them probably scattered the disease elsewhere. The effect of such an epidemic is far-reaching.

One episode of the epidemic is worthy of special mention, namely, a secondary outbreak which resulted from the infection of a well. This well had become popular among the residents of a certain district at the time when the public supply came to be distrusted, and its good quality was taken for granted. But the wife of the owner was taken sick with typhoid fever during the epidemic, and her dejecta passed without disinfection through the water-closet, and into a drain-pipe which ran within three or four feet of the well. The joints of the drain-pipe were insecure; and the well water, which had probably been for some time grossly contaminated, finally became infected. As a result, about fifty cases of typhoid fever and five deaths were traced to people who used this well water.

The Scranton Epidemic. Scranton is a coal-mining and manufacturing city of about 119,000 inhabitants in the eastern part of Pennsylvania. Until December, 1906, it had had a fairly satisfactory typhoid fever record. The water-supply of the city was taken chiefly from impounding reservoirs on Roaring Brook, south of the city, and delivered to the city by gravity. The main storage basin, known as Elmhurst Reservoir, had a capacity of about 1400 million gallons, or nearly 50 days' supply. From it the water flowed through an open stream several miles long, to what is known as No. 7 Reservoir, the starting-point of the city mains. No. 7 Reservoir had a capacity of about 100,000,000 gallons, and the distance from inlet to outlet was only about 2000 feet. Provision was made for carrying the water direct from the Elmhurst Reservoir to the city, if desired, without passing through No. 7 Reservoir, and the pipes were so arranged that any excess of water in Roaring Brook could be diverted and stored in Scranton Lake, on a neighboring watershed, for use during the summer. The Roaring Brook supply in 1906 furnished the greater part of the 30 million gallons per day used by the city. The other supplies, also impounded surface waters, were not concerned in the epidemic, and need not be considered.

Until the last of October, 1906, the Roaring Brook water was delivered to the city by allowing it to flow through the No. 7 Reservoir, but at that time this reservoir was cut off, and the water was furnished direct from Elmhurst, being taken from a point near the bottom.

Although thought to be of good quality, the water-supply was open to contamination at various points. Roaring Brook flowed through the center of Moscow, a village of about eight hundred people, only a mile above Elmhurst Reservoir, and the borough of Elmhurst bordered the brook below the reservoir. The main lines of the Delaware, Lackawanna & Western Railroad crossed and recrossed the brook, thus offering opportunities for contamination with excrement dropped from the passenger coaches or deposited by laborers along the track.

In some way or other the Elmhurst Reservoir became infected with typhoid bacilli during the latter part of November, 1906, but, although diligent search was made by the State Department of Health, the origin of the infection was not discovered. But that the water was infected was made clear by the statistics of the epidemic and by the analyses which were made of the water.[1]

The use of this infected water gave rise to an epidemic which extended over the months of December, January, and February, and which resulted in 1155 reported cases and 111 deaths during this time. The progress of the epidemic is shown by the following figures:

Week Ending —	Reported Typhoid Cases.	Week Ending —	Reported Typhoid Cases.
December 8, 1906	14	January 12, 1907	74
December 15, 1906	70	January 19, 1907	45
December 22, 1906	368	January 26, 1907	36
December 29, 1906	269	February 2, 1907	11
January 5, 1907	189		

The epidemic began the first week in December, 1906. On November 15, there had been a heavy snow-storm, and this was followed by rains on the 18th and 21st, and on December 3, 6, 10, and 15, one or more of which may have been the means of washing the infectious matter into the reservoir. The Elmhurst water was shut off on December 15, and the city supplied from Lake Scranton; and soon after, the epidemic began to subside. The typhoid fever in the city occurred almost exclusively among the users of Elmhurst water.

Dr. Wainright, in commenting on the Scranton

[1] It is believed that in at least one sample of this water, the typhoid bacillus was positively identified.

epidemic, refers to a subject which is too often overlooked. He says: —

"One point which I had not fully appreciated, and which, I think, most fail to appreciate, is that typhoid is to a certain extent a directly communicable disease. The Scranton experience has impressed this on me forcibly. Thus, there were 54 families in which there were two cases, and in at least 22 of these the second

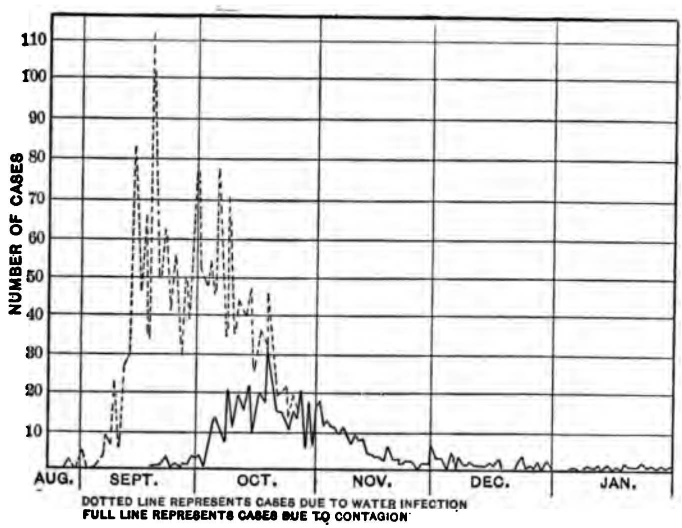


FIG. 12.

Diagram Showing the Progress of the Typhoid Epidemic in Gelsenkirchen, Germany.

person afflicted was definitely found to be the attendant to the patient. There were 7 families which had three cases, and 9 families which had four cases. Among these 16 families having three and four cases, in 8 the attendant was definitely known to have been one of the secondary cases. An interesting fact is that in the families where more than one case occurred, unusual numbers of the secondary cases were children. For example, in the three- and four-case families, out of 35 cases for which I have data as to age, sixty per cent were children."

In further emphasis of this point, reference may be made to an epidemic of typhoid fever in Gelsenkirchen, Germany, where a separation of the contact cases from those due to water infection was carefully made. The relative effect of the secondary cases and their tardy occurrence in the epidemic is shown by Fig. 12.

One discouraging feature of the Scranton epidemic was the fact that its existence was not recognized by the health department until it was well under way. Wainright says that "it was the chance finding of a reporter and the recognition of its seriousness by an editor that prevented further fatal delay."

From a strictly scientific standpoint, perhaps the most interesting fact about this epidemic is the demonstration that a great reservoir holding nearly a billion and a half gallons of water can become so thoroughly infected with typhoid bacilli as to cause an epidemic that extended over a period of several weeks.

The Epidemics of Lowell and Lawrence. During the years 1890–1891 a typhoid fever epidemic occurred in Lowell and Lawrence, Mass. As this epidemic illustrates better than almost any other what occurs on streams which are used both as sources of water-supply and as receptacles for sewage, it deserves more than passing mention. Both cities are on the Merrimac River, a large stream flowing through New Hampshire and Northern Massachusetts. On the banks of the Merrimac there are a number of large cities and towns, the most important of which are Concord and Nashua in New Hampshire, and Lowell, Lawrence, Haverhill, and Newburyport in Massachusetts. On the tributaries of the Merrimac are Fitchburg, Clinton, and Marlboro. The sewage of all of these cities finds its way into the river.[1]

The water of the river, therefore, was subject to fecal contamination throughout its course.

The epidemic first broke out in Lowell in September, 1890, and continued for about five months, during which new cases occurred as follows:

Date.	Cases of Typhoid Fever.
September, 1890	47
October, 1890	95
November, 1890	171
December, 1890	159
January, 1891	78
	550

This epidemic was studied by Professor William T. Sedgwick, who made a most thorough investigation. The situation was complicated by the fact that there

[1] In 1890 these cities had the following populations:

Lowell	77,696	Concord	17,004
Lawrence	44,654	Fitchburg	22,037
Manchester	44,126	Newburyport	13,947
Haverhill	27,412	Marlboro	13,805
Nashua	19,311	Clinton	10,424

were several distinct systems of water-supply in Lowell. The principal supply of the city was taken partly from a filter gallery, but chiefly from the Merrimac River without purification, the two waters being mixed and pumped together into the city reservoirs. The second system was owned by the Proprietors of Locks and Canals, and was used chiefly for fire purposes, but to some extent for drinking. The supply was river water taken from the canal, and was furnished to most of the mills. There was a third system also taken from the canals and used in a similar way. The fourth and fifth supplies were driven wells and spring waters, which were considerably used on account of the disagreeable qualities of the river water. Professor Sedgwick's investigation resulted in tracing the infection to the river water, and connected the beginning of the epidemic with an outbreak which occurred at North Chelmsford, a suburb of Lowell, where there were several cases of typhoid fever in houses that had privies overhanging Stony Brook, a tributary of the Merrimac River.

A short time after the epidemic in Lowell, typhoid fever broke out in Lawrence, nine miles down stream, and rapidly increased. The relation between these two epidemics was most striking. Lowell discharged its sewage into the river, — Lawrence drank the water without filtration. The water-supply of Lawrence was consequently infected with the fecal discharges of the typhoid fever patients in Lowell, and the epidemic followed as an inevitable result. The relation between these two epidemics may be seen from the following figures:

Month.	Lowell.		Lawrence.	
	Number of Deaths.	Death-rate per 100,000.	Number of Deaths.	Death-rate per 100,000.
August, 1890	7	9.02	1	2.24
September, 1890	8	10.31	3	6.73
October, 1890	10	12.88	3	6.73
November, 1890	28	36.08	7	15.71
December, 1890	26	33.51	19	42.64
January, 1891	19	24.48	19	42.64
February, 1891	14	18.02	11	24.69
March, 1891	10	12.88	6	13.46
April, 1891	6	7.73	3	6.73
May, 1891	4	5.15	2	4.49

It will be seen from these figures and from Fig. 13 that the climax of the Lawrence epidemic occurred about one month after that in Lowell.

In 1892 there was a repetition of this epidemic. Typhoid fever in Lowell was again responsible for an increase of typhoid fever in Lawrence. The situation was not as serious as that of two years before, but this time Newburyport was also affected. The relation between the three cities is shown by the following figures:

Date.	Lowell.		Lawrence.		Newburyport.	
	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.
November, 1892	19	3	14	4	0	0
December, 1892	70	10	32	9	4	1
January, 1893	38	10	72	3	28	3
February, 1893	14	7	23	12	9	0
March, 1893	...	4	...	4	...	1

It is said the reason for the Newburyport epidemic was that the " Newburyport water company had distributed to the cities more or less water drawn unpurified directly from the Merrimac River, contrary to recent specific advice of the danger of so doing addressed to them by the State Board of Health, and referring especially to the

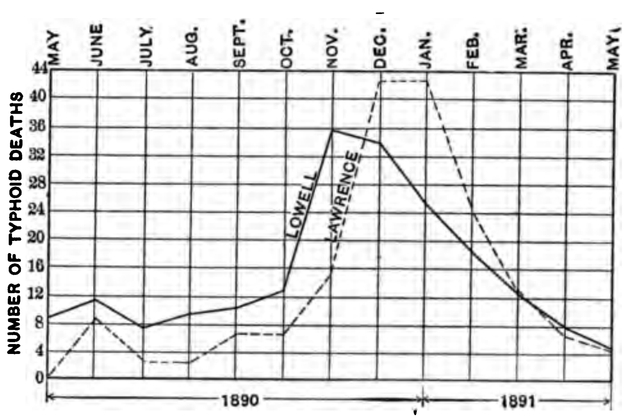


Fig. 13.

Diagram Showing the Chronological Relation between the Lowell and Lawrence Typhoid Fever Epidemics.

likelihood of an outbreak of typhoid fever if they should continue to do so."

In justice to these cities, it should be said that they now have safe and wholesome water-supplies. Lowell abandoned the river, and introduced a ground water-supply, while at Lawrence a filtration plant was constructed which has very materially reduced the amount of typhoid fever in that city.

The Epidemics of Waterville and Augusta. In 1902–3, an epidemic of typhoid fever occurred in the cities of Waterville and Augusta, Me., which furnishes an incident almost parallel to the Lowell and Lawrence epidemic of 1890–1. These cities are situated on the Kennebec River. Augusta is the capital of the state, and Waterville, 18 miles up the river, is an important manufacturing city.

The city of Waterville was supplied with water from the Messalonskee system by the Maine Water Company, which also furnished water to the neighboring towns of Fairfield, Winslow, and Benton. The system has a watershed of 205 square miles, and drains a chain of large lakes. The population on the watershed was 27 per square mile, the principal source of pollution being the town of Oakland, 7 miles above the pumping station, where the population was about 2000.

Waterville discharged its sewage into the Kennebec River. Augusta, at this time, took its supply from the river at a point just above the city near the Kennebec dam. The water was pumped to a reservoir through an old Warren filter, one of the first of its kind in America. This was a filter only in name; it was really no more than a strainer, and wholly inefficient in removing disease germs from the water. Augusta discharged its sewage into the river.

The town of Richmond, 15 miles below Augusta, also took its water unpurified from the Kennebec River.

The epidemic was very carefully studied by the author, assisted by Dr. E. C. Levy and Mr. Langdon Pearse, in connection with the appraisals of the waterworks of the two cities, as it was necessary to prove in court the probable origin of the trouble and its connection with the public water-supplies. In fact, it was largely due to these epidemics that steps were taken to transfer the ownership of the works from the private water companies to the water districts, which represented the people.

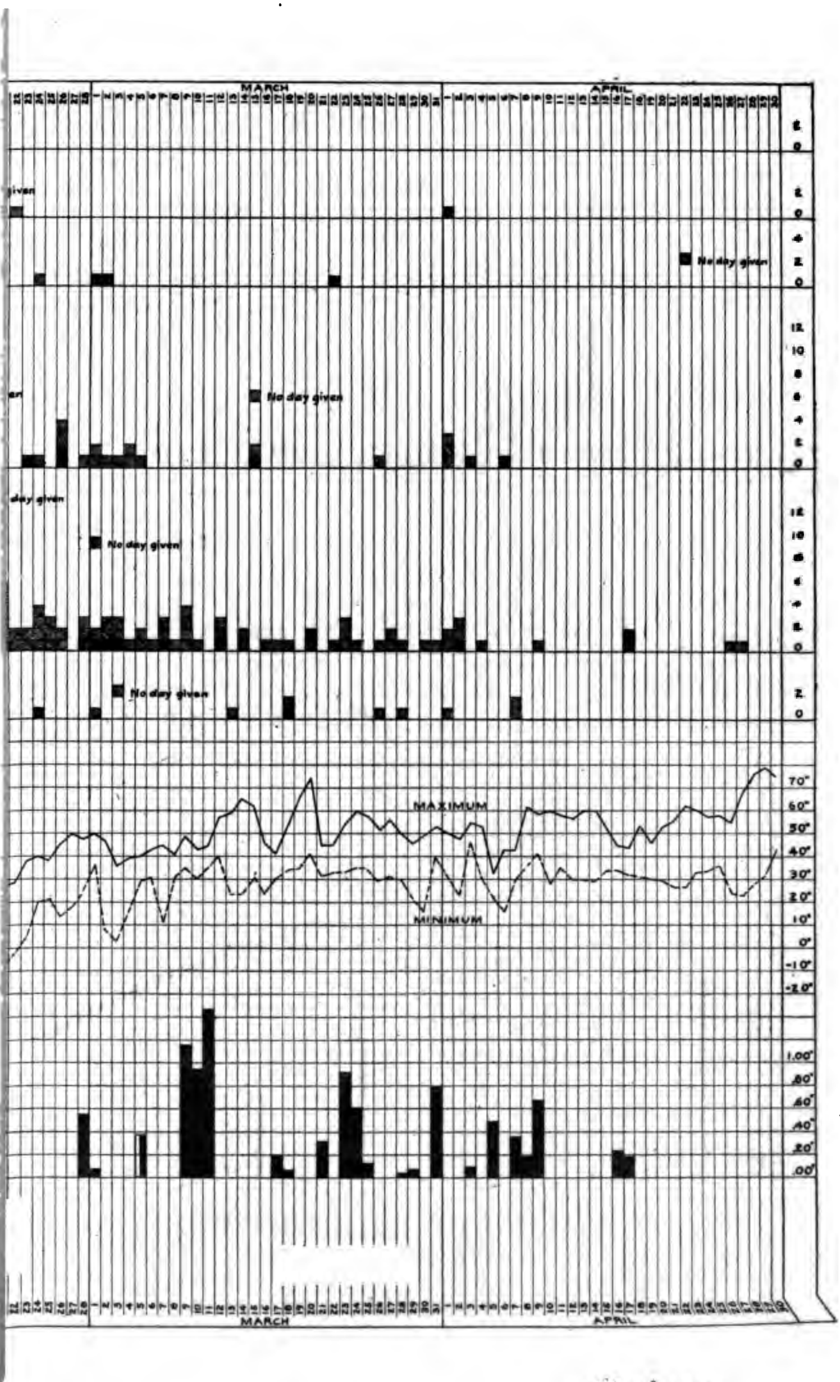
The epidemic was first noticed at Waterville, in November, 1902. For about a month new cases were reported at the rate of one a day. On Christmas Day there were five new cases, and during the next week the daily number of cases was about the same. Thirteen were reported on New Year's Day. After the middle of January the number of new cases fell off, but they continued to be reported at intervals until March. In Fairfield, Winslow, and Benton, typhoid fever occurred at the same time. The largest number of cases was reported during the first two weeks of January. These four communities had the same water-supply, namely, that of the Messalonskee River, and from the first it was evident that this was the cause of the epidemic.

As the sewage of these typhoid-fever-stricken communities emptied into the Kennebec River, and as the water of this river furnished the supply of Augusta, it was almost inevitable that the epidemic should extend to that city also, and this is what actually occurred. During the latter part of November and the whole of December new cases of typhoid fever occurred daily in Augusta. It seems probable that these earlier cases were due to the same source of infection that caused the epidemic at Waterville, inasmuch as the Messalonskee River, which supplied that city, discharged into the Kennebec above Augusta. It was not until about two weeks after the climax of the Waterville epidemic that the serious period of the Augusta epidemic began. During the latter part of December and throughout the months of January and February the sewage at Waterville must have been infected with typhoid fever bacilli; and, making due allowances for the periods of sickness, transmission, and incubation, this time corresponded with the duration of the epidemic at Augusta. After the Waterville epidemic had ceased and sufficient time had elapsed for the patients to recover, the epidemic at Augusta came to an end.

At Richmond, which is only a small village, typhoid fever did not occur until the middle of January; but occasionally cases appeared during the next two or three months, and were plainly connected with the epidemic of the cities above.

Fig. 14 shows chronologically the progress of this epidemic, together with certain factors which affected it. It indicates that the epidemics in the different communities formed a connecting series, and may be really considered as one epidemic, inasmuch as they started from a common cause. In all there were about 612 cases and 53 deaths.

The epidemic at Waterville was traced to two cases of typhoid fever which occurred on the watershed above the intake. The first of these was at the city almshouse located in the suburbs of Waterville only a few hundred feet from the stream. On September 22, 1902, a typhoid fever patient was admitted to the almshouse. His attack was a mild one, and he was confined to his bed for only a week; but after leaving his bed he remained


MARCH
APRIL
No day given
No day given
No day given
No day given
MAXIMUM
MINIMUM
70°
60°
50°
40°
30°
20°
10°
0°
-10°
-20°
1.00"
.80"
.60"
.40"
.20"
.00"

five days at the almshouse, and during this latter period no attempt was made to disinfect either his excreta or urine, which were deposited sometimes in a privy in the yard, and sometimes in a water-closet which drained into a cesspool on the premises. On November 6, both the privy and cesspool were cleaned and their contents spread upon the almshouse garden, the ground being frozen at this time. The slope of the garden was towards the river.

The second case occurred about a mile outside of Waterville, in the family of a milkman. During 1902 there had been five cases of typhoid fever in this house. In all of these cases except one, a prompt diagnosis had been made, and the dejecta were properly disinfected and buried, but in one case the patient was ill for several weeks before the diagnosis was made. During this time, i.e., from September 1st to 25th, 1902, disinfection was not practiced, and the stools were emptied into the privy vault. Early in November the privy was cleaned and the contents deposited on a field away from the house at a point where the land sloped abruptly towards a brook 200 feet distant, this brook being tributary to the Messalonskee Stream three-quarters of a mile away. Both the almshouse and the mouth of this stream were about one mile distant from the waterworks intake.

Thus, early in November, 1902, typhoid fever dejecta had been deposited upon the surface of frozen ground at two points relatively near the pumping station. During November and the first part of December the rainfall was light, and there was some snow, but apparently during this time small amounts of infectious matter were washed into the stream. On the 16th of December there was a heavy rain, and nine days later, on Christmas Day, the main epidemic began. The heaviest rainfall, after the infectious material was deposited on the fields occurred on December 22, with a precipitation amounting to 1.3 inches. Ten days after this, or almost exactly the same interval as after the rainfall of December 16, there developed the greatest number of cases of any which occurred during the epidemic. Throughout the two months, from the last third of November until the corresponding time in January, the relation between the rainfall in typhoid fever cases was manifest. About the middle of January the typhoid bacilli had either lost their vitality, or had been washed away, as subsequent heavy rainfalls were not followed by serious consequences.

Profiting by their experience, the cities of Waterville and Augusta have both abandoned the use of the river water, and now take their supplies from lakes at a considerable distance from the city.

The Pittsburg and Allegheny Epidemics. For many years the cities of Pittsburg and Allegheny, Pa., have been in the throes of a typhoid fever epidemic which has spread its baneful influences over the western part of the state, and scattered the disease even more widely through the agency of many an unfortunate visitor and traveling man. It is one of the black records in the sanitary history of our country.

These two cities are situated at the confluence of the Allegheny and Monongahela Rivers, — where they unite to form the Ohio River. In 1900 Pittsburg had a population of 321,616, and Allegheny 129,896.

Pittsburg takes its water from the Allegheny River at Brilliant Station, six miles above the junction of the rivers, and from the Monongahela River, at a point three miles above the junction. The first-named supply is under municipal control, and furnishes about three-quarters of the supply delivered between the rivers in Wards 1 to 23. The second is operated by a private company, and supplies Wards 24 to 36, south of the Monongahela River. In neither case is the water purified, and the period of storage in the distribution reservoir is inconsiderable. Both rivers are contaminated by the sewage of large communities, some of them only a few miles from the city. The water is at times muddy and disagreeable. The urban population in 1900 was 28 per square mile on the Allegheny River, and 26 per square mile on the Monongahela.

The statistical data showing the occurrence of typhoid fever are given elsewhere in this volume, so that in this connection it is only necessary to state that in this unfortunate city there occur annually upwards of 5000 cases of the disease. It is scattered all over the city, but, on the whole, the wards supplied with Allegheny water suffer the most. It is present at all seasons, but is more prevalent in the fall and winter months than in cities supplied with good water.

The Pittsburg case is instructive, as it illustrates the dangers of procrastination. Ten years ago and more, it was known that the public water-supplies were infected.

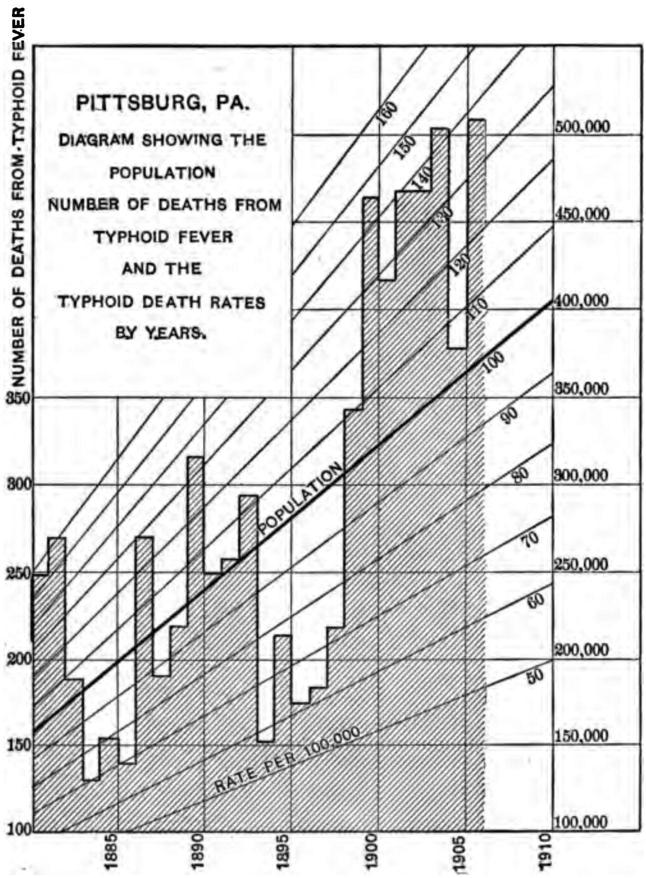

PITTSBURG, PA.
DIAGRAM SHOWING THE
POPULATION
NUMBER OF DEATHS FROM
TYPHOID FEVER
AND THE
TYPHOID DEATH RATES
BY YEARS.
NUMBER OF DEATHS FROM TYPHOID FEVER
POPULATION
RATE PER 100,000
160
150
140
130
120
110
100
90
80
70
60
50
350
300
250
200
150
100
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
1885
1890
1895
1900
1905
1910

FIG. 15.

The best methods of filtering the supply were determined in 1898 by an elaborate series of experiments. Delays followed, and, although a filter plant is now under construction and nearly completed, it is not yet ready for use.[1] The delay has cost the city at least 2000 lives, — possibly 3000, — and has brought unnecessary sickness into more thousands of homes.

The case of Allegheny is equally bad. The water-supply is taken from the Allegheny River at Montrose, 10 miles from the Point, and is drawn from a rock-filled crib. It is practically unfiltered water, grossly contaminated. Allegheny is smaller than Pittsburg, but its typhoid fever death-rate has been even higher.

These communities have been singled out for comment not because they are the only instances of epidemics due to long-continued contamination of the water-supply, or because they are the only cities which have failed to live up to the light within them. Philadelphia has been equally culpable, and other cities might be named. Pittsburg, however, is a very clear-cut case.

The Chicago Epidemic. Chicago, the second largest city in the United States, situated on Lake Michigan, had for many years a water-supply that was constantly being contaminated with the discharges of her own sewers. The water was taken from the lake opposite the city at several "cribs," which were 1.5 to 4 miles off shore. Sewers were discharged all along the water-front; while the Chicago River, penetrating the city with its north and south branches, and polluted almost beyond endurance, flowed into the lake about midway between the

[1](January, 1908.)

upper and lower cribs. That intense pollution of the lake water, and hence of the water-supply of the city, resulted from this situation was well known. It needed no elaborate studies, for at times the foul river water could be traced to the intakes with the eye.

This intolerable situation resulted in the building of the Chicago Drainage Canal, the object of which was to take the sewage out of the lake and carry it westward down the DesPlaines and Illinois rivers into the Mississippi, — a project, recently consummated, which has given rise to some important litigation before the United States Supreme Court between the states of Missouri and Illinois. By the construction of this canal the flow of the Chicago River was reversed, so that, instead of the sewage entering the lake and polluting the water-supply, the water of Lake Michigan with the greater part of the sewage now flows westward to the Mississippi and to the Gulf of Mexico. Whatever the effect of this has been on the cities along the Illinois and Mississippi rivers, this canal has improved the water-supply and reduced the amount of typhoid fever in Chicago.

As an illustration of an epidemic caused by contaminated lake water, the Chicago situation during the years 1890, 1891, and 1892 affords an important example. Within one fatal year nearly 2400 of the inhabitants died from typhoid fever, and these deaths probably represented at least 25,000 cases. The following figures show the number of deaths each month:

Month.	Deaths from Typhoid Fever.		
	1890.	1891.	1892.
January	53	67	311
February	136	61	187
March	103	71	76
April	45	136	56
May	82	408	70
June	107	167	55
July	86	200	211
August	115	182	179
September	95	198	138
October	72	171	92
November	67	150	67
December	47	186	47
Total	1008	1997	1489

Although typhoid fever had been very abundant in 1890, the greatest period of the epidemic began in April, 1891. It continued without a break for nearly a year; then came a decrease, and then for several months the deaths increased again.

Epidemics due to lake pollution are quite likely to be of long duration, for the reason that, as the epidemic increases in severity, the sewage of the city becomes more and more infected, and this increases the number of typhoid bacilli in the water. Such an epidemic tends to perpetuate itself, and may continue until all susceptible persons have had the disease, or until the conditions of winds, currents, etc., are such that for a time the contamination of the water ceases.

In 1902 another epidemic occurred in Chicago, —

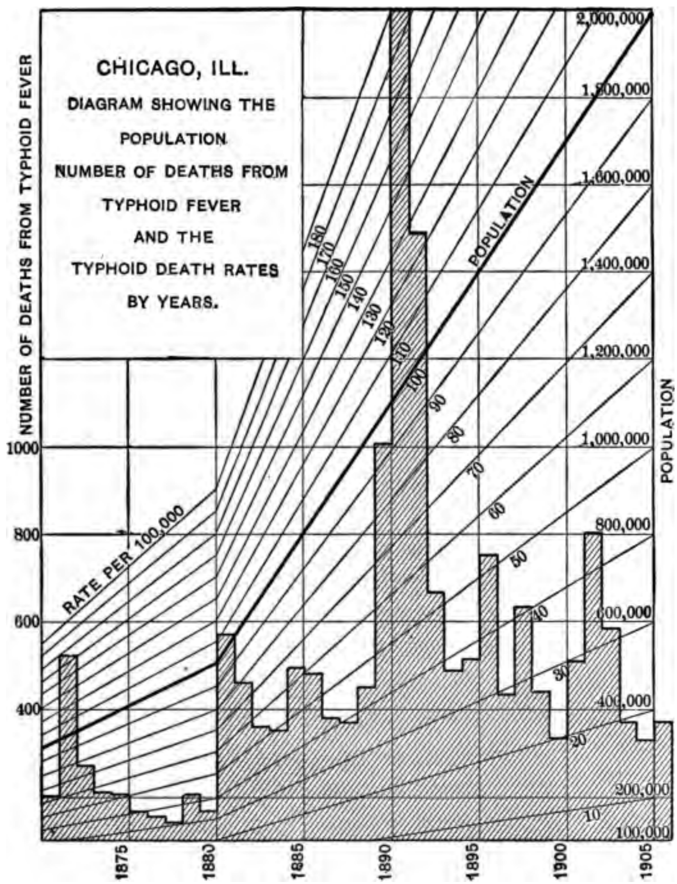

CHICAGO, ILL.
DIAGRAM SHOWING THE POPULATION NUMBER OF DEATHS FROM TYPHOID FEVER AND THE TYPHOID DEATH RATES BY YEARS.
NUMBER OF DEATHS FROM TYPHOID FEVER
POPULATION
RATE PER 100,000
1000
800
600
400
2,000,000
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
100,000
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1875
1880
1885
1890
1895
1900
1905

FIG. 16.

less in magnitude than the one just described, but yet one which caused the annual number of deaths to increase from 337 in 1900, to 509 in 1901, and 801 in 1902. This epidemic came as a surprise to many of the citizens of Chicago, as they had been led to believe that the new drainage canal would effectually act as a safeguard to the water-supply. But the explanation was obvious. Although the drainage canal was opened in 1900, not all of the sewers had been connected with it, — the intercepting sewer along the south shore, and the Lawrence Avenue sewer on the north side, for example, had not been completed, — so that a considerable part of the city continued to discharge its sewage into the lake. The epidemic began early in the summer. The 193 persons who died in August probably contracted the disease in June or July. It was noticed that the rainfall during May, June, and July of that year had been exceptionally heavy, — larger, in fact, than for any corresponding period since the epidemic of 1892.[1]

At most times the typhoid fever records of the city show a general correspondence between the rainfall and the occurrence of typhoid fever, although, as might be expected, this relation has not been quite as marked

[1]

Year	Rainfall during May, June, and July.
1892	19.58
1893	8.60
1894	5.91
1895	5.70
1896	10.59
1897	5.91
1898	9.47
1899	13.72
1900	10.29
1901	8.85
1902	17.31

since the drainage canal was put in service as it was before. The annual report of the Department of Health for 1906 refers to the low rainfall of that year as one reason for a reduced typhoid death-rate.

Recently the typhoid death-rate in Chicago has been lower than formerly; but from the nature of the sanitary conditions along the water-front, and the inevitable contamination of the water resulting from shipping and other causes, there is no reason to expect that the city will ever have a permanently low typhoid death-rate until the lake water is filtered.

The Cleveland Epidemic. Another instance of an epidemic caused by contaminated lake water is that of Cleveland, Ohio.

The city of Cleveland is situated on an indentation in the southern shores of Lake Erie, about two-thirds of the way from Toledo to Buffalo. This indentation, or bay, is about 40 miles long and 7 miles wide, and within it the water is nowhere deeper than 60 feet. The Cuyahoga River flows into the lake through the heart of the city.

The water-supply of the city is derived entirely from the lake. The old intake, which was used until 1904, was located about 1¼ miles from the shore and 1 mile west of the mouth of the river, the water being taken at depths of 12 to 28 feet below the surface, and conveyed by two tunnels to the pumping station at Division Street. In order to supply a greater quantity of water, and at the same time to secure water of a better quality, new works were begun in 1890 and completed in 1904. The new intake is located 4 miles from the shore, almost opposite the mouth of the Cuyahoga River. From the steel crib a 9-foot tunnel conveys the water to a pumping station on the shore of the lake at Kirtland Street.

All of the sewage of the city flows directly or indirectly into the lake. About one-half of it flows into the Cuyahoga River, and the rest empties directly into the lake along the water-front. It has been estimated that the amount of solid matter discharged into the lake through these sewers amounts to 100 tons a day, while the number of bacteria contained in it amounts to more than 100 million billion. These figures are incomprehensible, and mean little except when taken in connection with the subject of dilution. Beside the pollution from the river and the sewers, the water-supply of the city was at that time endangered by the practice of dumping dredged material from the river at points dangerously near the intakes.

During the year 1903, when the water-supply was drawn wholly from the old intake, a severe epidemic broke out in the city. This continued throughout the entire year, and extended over the spring months of 1904, ending only with the introduction of water from a new source.

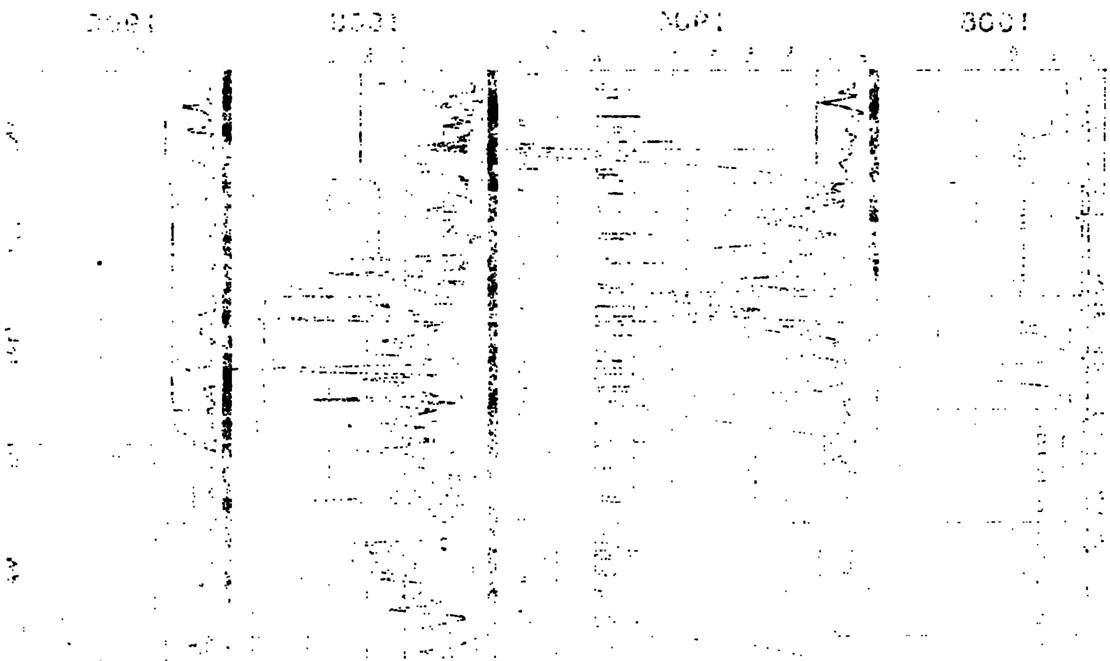
In order to understand the course of this epidemic, it is necessary to know that under ordinary conditions the Cuyahoga River water and the sewage of the city become so thoroughly mixed and diluted with the water of the lake that the effect of contamination is not serious a mile or two out from the shore, but that at times of heavy rains which cause floods in the river, and especially at those times when the floods occur in connection with an off-shore wind, pollution reaches the old intake crib in such quantities as to grossly contaminate the water-supply. A study of the typhoid data prior to 1903 showed that after severe southeasterly storms there was likely to be an increase of the disease in the city. The investigations made in connection with the epidemic referred to showed that at the point where the new intake was located, 4 miles off the shore, the influence of the city sewage on the lake water was extremely slight, although, even at that distance, there were times when traces of it could be detected.

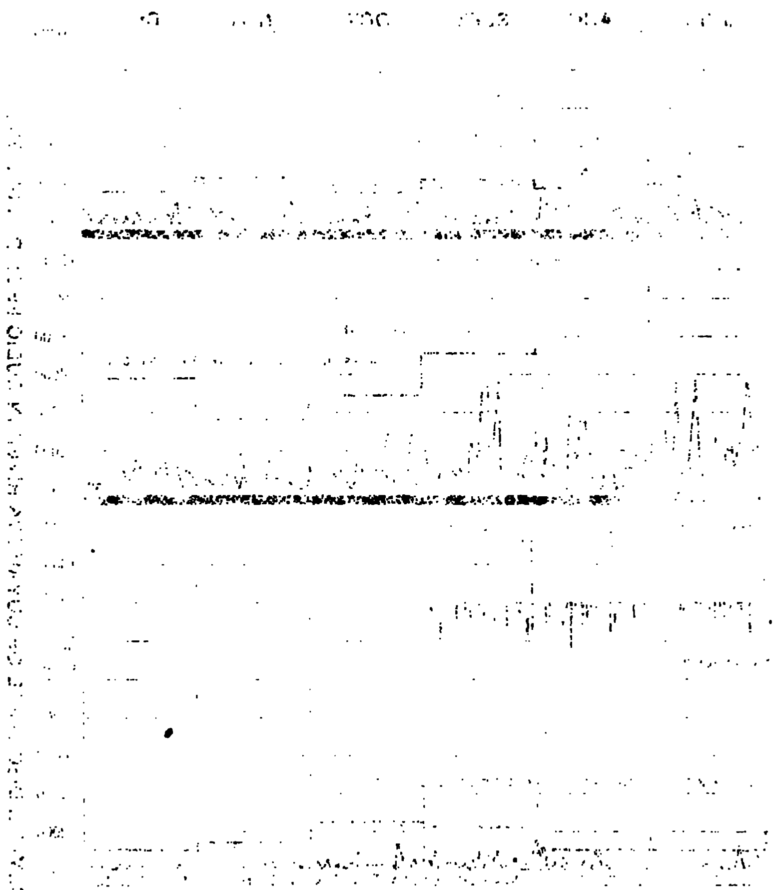
The epidemic of 1903 began on January 6, when 9 new cases were reported. Ten days before this there had been a heavy rainfall which increased the discharge of the river, and which was followed by fresh south-easterly winds.

It is unnecessary to explain here all the fluctuations in the typhoid morbidity which occurred during this year, but the data show that the wind exerted the controlling influence on the typhoid fever in the city. (See Fig. 17.) During the year 1903 the total number of cases reported was 3443, and there were 472 deaths.

The severest part of the epidemic occurred early in 1904, beginning after a memorable flood on January 20, 21, and 22.

On these three days the rainfall aggregated 2.57 inches, while the wind blew strongly from the south-east. Moreover, on the day preceding this storm the southeasterly wind movement had been 515 miles. On January 21, the discharge of the Cuyahoga River was





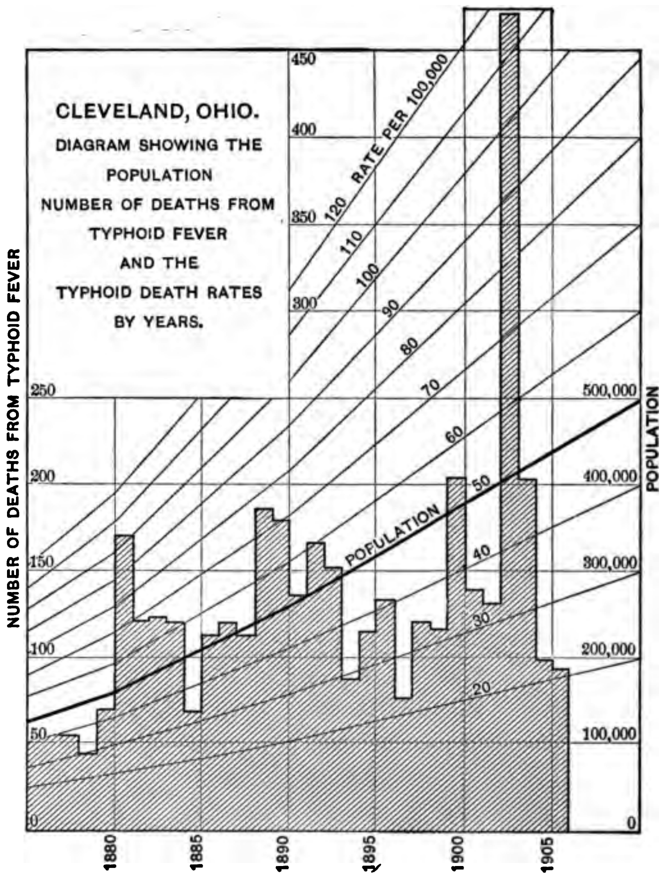

CLEVELAND, OHIO.
DIAGRAM SHOWING THE
POPULATION
NUMBER OF DEATHS FROM
TYPHOID FEVER
AND THE
TYPHOID DEATH RATES
BY YEARS.
NUMBER OF DEATHS FROM TYPHOID FEVER
POPULATION
RATE PER 100,000
120
110
100
90
80
70
60
50
40
30
20
450
400
350
300
250
200
150
100
50
0
500,000
400,000
300,000
200,000
100,000
0
1880
1885
1890
1895
1900
1905

FIG. 18.

very great, and immense quantities of mud were carried into the lake, possibly 200,000 cubic yards, or more than is ordinarily discharged during an entire year. On January 31, ten days after this flood, typhoid fever began to increase in the city, and this increase continued until February 10, when 25 new cases were reported in one day. On February 6 and 7, there was another southeasterly storm which caused a flood in the river. Although the stream discharge was less than before, the sewage of the city had become so thoroughly infected that the amount of typhoid in the city increased more than before. A week of calm weather followed, and the amount of typhoid fever in the city dropped off. On the 13th and 14th of February there was another strong southeast wind, and ten days afterward the morbidity rate rose again, and so the epidemic continued until a change came in the source of supply.

During the 16 months from January, 1903, until May, 1904, there were 4578 cases of typhoid fever reported to the Health Department, and 611 deaths.

The introduction of water from the new intake occurred gradually. The Kirtland Street station, where water was taken from the new intake, was started on February 10, 1904, and the pumps at the Division Street station, the old supply, were finally shut down on April 7. Between these two days, water was drawn from both intakes. As the proportion of water from the new intake increased, the typhoid fever in the city began to disappear, and finally, after the old supply had been entirely abandoned, the epidemic ceased. The following figures show the close relation between this change in the character of the water-supply from bad to good, and the decrease in the typhoid fever.

Period.	Average Number of New Cases of Typhoid Fever Reported Daily.
January 1, to January 31, 1904: Period prior to the epidemic caused by flood	2.84
February 1 to March 5: Period of epidemic corresponding to exclusive use of old supply	20.91
March 6 to March 15: Period of epidemic corresponding to use of one-half of supply from new intake and one-half from old intake	11.10
March 16 to April 21: Period of epidemic corresponding to use of three-quarters of supply from new intake	2.89
April 22 to December 31: Period corresponding to exclusive use of water from new intake	1.03

The Burlington Epidemics. The city of Burlington, Vermont, is located on Lake Champlain. In 1866 it introduced a water-supply, taking the water from the lake at one of the docks near the city where the pumping station was located. Somewhat later, sewers were built which discharged into the lake less than half a mile away from the waterworks intake; but in 1885, on account of excessive pollution, the outfall sewer was removed to a distance of one mile. This, however, did not relieve the situation, and typhoid fever and other forms of diarrheal diseases were prevalent until 1894, when the waterworks intake was extended two miles and a half into the lake to a point near Appletree Island.

After this change in the supply there was a reduction of typhoid fever in the city; but during the last ten years, the death-rates have shown a tendency to increase, while

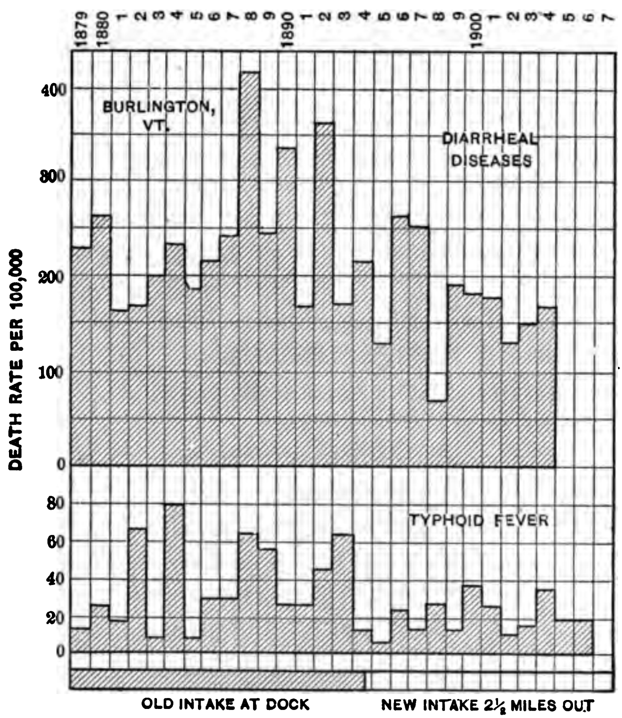


FIG. 19.

Diagram Showing the Relation between the Water-Supply and the Typhoid Fever Death-rates at Burlington, Vt.

the diarrheal diseases have remained prevalent. In consequence of this continued pollution, which comes partly from the city itself, and partly from towns draining into the Winooski River, which enters the lake not far away, the city decided in 1907 to build a filter plant. This is now under construction.[1]

The Butler Epidemic. Butler, Pa., is a borough in the western part of the state fifty miles north of Pittsburg. In 1903, when the epidemic occurred, it had a population of about 16,000. The water-supply was taken from a reservoir on the Connoquenessing Creek, filtered and pumped into the city mains. Originally, the water had been taken directly from the creek, and the old connection remained. The creek at this point was subject to certain gross pollutions, and this was the occasion for constructing a reservoir at Boydstown, seven miles above Butler, and a second reservoir on Thorn Run. The filter plant was a mechanical filter of the "pressure" type. Carefully operated, it was fairly efficient, but it cannot be compared in efficiency to one of our modern gravity filter plants.

In the course of some alterations that were being made in the pipe connections at the pumping station, this filter plant was put out of service between October 20 and 31, 1903; and because of the failure of the dam of the Boydstown reservoir on August 27, water was being drawn at this time from the old intake,— that is, directly from the creek, and close to the borough limits.

Ten days after the filter was shut down, — that is, during the first week of November, — the epidemic broke out in all parts of the borough. It increased in severity and continued for several weeks. Between November 1

[1] January, 1908.

and December 17, 1903, there were 1270 cases and 56 deaths.

Dr. George A. Soper, who made a careful study of the epidemic, secured information regarding several cases of typhoid fever which had occurred on the watershed, — some of them within half a mile of the pumping station and above the intake, and others near a brook that enters the creek within 100 feet of the filter plant. The creek water, therefore, had ample opportunities for infection. The filter had been the only protection to the water consumers during the summer, and the withdrawal of this protection led to the epidemic.

In a certain sense the Butler epidemic may be called an "accidental one," yet, in view of the known pollution of the creek, it is difficult to see how the exigencies of the case could have justified the temporary shutting down of the filter. It was certainly done at great risk, and the result carries with it a lesson that should be heeded.

The Butler waterworks were owned and operated by a private company; and the question has been asked more than once, — "Would such a risk have been assumed if the works had been operated under municipal ownership?" It is an interesting question.

The Lowell Epidemic of 1902. Since 1896 the city of Lowell, Mass., has been supplied with driven-well water, and the amount of typhoid fever in the city has been comparatively low.

In August, 1903, there was a sudden increase of typhoid fever, as shown by the following statistics:

TYPHOID FEVER STATISTICS BY WEEKS AT LOWELL, MASS., IN SUMMERS OF 1901, 1902, AND 1903.

1901.			1902.			1903.		
Week Ending—	Cases.	Deaths.	Week Ending —	Cases.	Deaths.	Week Ending —	Cases.	Deaths.
Aug. 3	0	0	Aug. 2	2	0	Aug. 1	0	1
" 10	1	0	" 9	1	1	" 8	0	0
" 17	0	0	" 16	0	1	" 15	13	0
" 24	1	0	" 23	2	0	" 22	75	1
" 31	4	0	" 30	0	1	" 29	41	1
Sept. 7	3	0	Sept. 6	4	2	Sept. 5	20	2
" 14	1	1	" 13	1	0	" 12	7	2
" 21	1	0	" 20	2	0	" 19	8	2
" 28	2	0	" 27	3	1	" 26	4	0
Total	13	1		15	6		168	9

During these two months there were 168 reported cases, as compared with 13 cases in 1901, and 15 cases in 1902, during similar periods. The outbreak was traced to a pollution of the water-supply of the city mains in the following manner:

The cotton mills of the city had a water-supply of their own derived from the Merrimac and used for fire protection. This system had several connections with the public supply of the city, controlled by check valves; and the arrangement was such that in case of a fire at the mills which made heavy demands for water, the valves would open and let water from the city mains into these pipes; when the pressure in these pipes was restored, the valves would close again.

On July 18, 1903, at 8 P.M., a large fire broke out in the mills of the Merrimac Manufacturing Company, and lasted until 2 A.M. the next day. Mr. George Bowers, the city engineer, has given the following account of what happened at that time:

"The recording pressure gauges show that soon after the fire began the check valves opened, and the city water flowed into the corporation pipes. Immediately after the fire the corporation began pumping to refill their reservoirs, but after several hours' work little headway had been made. This led to an investigation, which revealed the fact that one of the check valves remained open when the increased pressure was applied, driving the polluted Merrimac River water into the city main, and mixing it with driven-well water at a point in the center of the city where there is a large consumption of water. In a few days a large number of people were taken violently ill, and an epidemic of cholera morbus ensued. In about three weeks a great many cases of typhoid fever were reported, followed by a serious epidemic of the same.

"At every connection is a gate controlled by the city, and these gates were closed soon after the typhoid fever broke out, and have remained closed. The city has placed extra hydrants in the streets near the corporations for their benefit, and the mills themselves are enlarging their own water-supply. In the spring the city will remove all connection between the two systems."

This occurrence illustrates in a striking manner the damage which a comparatively small amount of polluted water may do.

This epidemic may be fairly termed one due to accident. Yet it is an accident that should have been avoided. Such connections of the city mains with fire service pipes supplied with impure water, as those at Lowell, are a source of danger. These connections are more common than is generally supposed. The insurance companies, in arranging their rates, favor those mills which are supplied with water from two independent sources, both available in case of fire. In some cities many of these objectionable connections exist.

Several recent instances might be cited where small outbreaks of typhoid fever have occurred in cities supplied with filtered water, and the filters have been unjustly blamed for a trouble which was really caused by these fire connections. In one case a very severe epidemic started in this way. It is well known by engineers that the check valves used in these cases do not always operate properly, — they seldom close absolutely tight, and sometimes they become stuck when wide open. Very seldom are they cared for after being installed, and often the pipes are covered with earth, so as to make the valves inaccessible without digging. It has been suggested that by the use of improved check valves, arranged in duplicate, ample protection of the quality of the city's supply may be secured, but it must be admitted that it is far safer to sever all connections of pipes carrying polluted water from the city mains. In many places the latter course is being drastically carried out.

The Millinocket Epidemic. Another instance of a typhoid fever epidemic due to an accidental pollution of the public water-supply which occurred as the result of a fire, was that of Millinocket, Maine, in 1904.

Millinocket is a paper-mill town recently established near the head waters of the Penobscot River, 84 miles above the city of Bangor. The village had a water-supply satisfactory in quality, but deficient in pressure. In case of fire it was necessary to pump water into the mains from the Millinocket River, a tributary of the Penobscot, and the place where this was done was at the paper mill below the town and below the outlet of the sewers.

On January 29, 1904, a fire occurred in the village, and this pump at the mill was used. As a result, there was an epidemic of diarrhea, or "winter cholera," during which more than 200 people were made sick.

On February 21, a second fire occurred. The mill pump was used, and it is said that for several days after the fire the polluted river water was pumped into the street mains, the gate not having been fully closed. This time an epidemic of typhoid fever resulted. It began on March 2, when 4 cases occurred, and developed gradually until more than 200 were made sick. Between March 1 and May 1, 16 persons died of the disease.

This epidemic had an unfortunate sequel. The sewage of Millinocket emptied into the Millinocket River and passed down into the Penobscot. Bangor, 84 miles below, used the river water imperfectly filtered, and so did the cities of Old Town and Brewer. In each of these places epidemics of typhoid fever occurred during the months of April and May. In all there were more than 600 cases: in Bangor alone, there were 36 deaths.

The far-reaching effect of the "accident" at Millinocket is seen from these facts. One cannot help wondering if the time will not come when some one will be held responsible for such "accidents."

The Baraboo Epidemic. An epidemic occurred in the town of Baraboo, Wis., during the summer of 1901, which may be considered as due to accident. It began in May and continued until October, during which 190 cases and 15 deaths occurred. The public water-supply was taken from ground water, but the suction pipe was laid through a flume which carried polluted water. At the pumping station there were two water-power pumps, — one used for pumping ground water to the city, and the other used for pumping river water from the flume for railroad uses. There was also a steam pump used as a reserve at times of low water, arranged so that it could pump either ground water or flume water. The season of 1901 had been dry, and the steam pump had been used more than usual. Comparison of the dates when the steam pumps were used, with the occurrence of the typhoid fever in the town, showed a direct correspondence between them; and an examination of the intake pipe showed that the foot valves in the suction pipe of the flume leaked so that when the steam pump was used, water from the flume was pumped into the supply. On repairing these leaks typhoid fever in the city immediately subsided.

An Outbreak on One of the Great Lakes Steamers. An interesting example of what was probably an accidental contamination of water occurred on one of the large passenger steamboats on the Great Lakes plying between Buffalo and Duluth. One of the victims has related the following incident:

"We left Buffalo on June 29, 1906, and passed Detroit about noon of the 31st. During the night following, about 30 or 40 passengers were taken violently ill with severe intestinal disturbances; and two or three weeks afterwards a number of these came down with typhoid fever, I being among the number. On inquiry I learned from one of the officers that the supply of drinking-water, usually taken from the middle of Lake Erie where it is pure and wholesome, had run short, and that the tanks had been filled in the Detroit River at a point not far below Detroit, that is in the path of the city's sewage."

The following summer there was another outbreak among the passengers and crew on the same steamer, which resulted in upwards of 70 typhoid cases and at least 5 deaths. Among those who contracted the disease were 5 musicians and 12 chambermaids employed on the boat, and some of the crew. An investigation of this outbreak was made by the Board of Health of Buffalo, which showed that the water in some of the tanks was contaminated, while the toilet rooms and kitchens of the boat were in an unsanitary condition. This led to an extensive cleansing of certain parts of the steamer, and to the disinfection of the water-supply tanks by the health authorities; and after some delay the vessel was allowed to clear from Buffalo, upon the agreement of the company to supply sterilized water for drinking purposes, and to duly notify the passengers and crew of the possible dangers of the tank water.

This is probably an exaggerated instance of something that occurs more or less frequently, and well illustrates the risks that one is compelled to run in traveling.

The Lausen Epidemic. Historically the typhoid epidemic which occurred in Lausen, Switzerland, is of great interest. It occurred as long ago as 1872, and was one of the very first instances where the disease was traced to the public drinking-water. It is interesting also from the remoteness of the source of infection.

Sedgwick, quoting from Dr. Hagler's report, has given the following account of the epidemic:

"The epidemic occurred in the little village of Lausen, which had a population of 780, and which up to that time had never suffered from typhoid fever. Suddenly, in August, an outbreak occurred which affected a large part of the population. Ten cases were reported on August 7, and they continued to increase until, at the end of the epidemic in October, 130 inhabitants had been taken sick, besides others who had spent their vacation in the village. The fever was distributed quite evenly throughout the town, with the exception of certain houses which derived their water from their own wells and not from the public supply.

A short distance south of Lausen was a little valley, the Fürlerthal, separated from Lausen by a hill, the Stockhalden, and in this valley on June 19, upon an isolated farm, a peasant fell ill with a very severe case of typhoid fever, and within the next month there occurred three other cases in the neighborhood. No one in Lausen knew anything about these cases until the outbreak occurred.

The water-supply of Lausen was taken from a well, or spring, at the foot of the Stockhalden Hill on the Lausen side. The well was walled up, covered, and apparently protected; but the distribution of the cases directed suspicion to this water as the source of the trouble, and an investigation showed that this suspicion was well founded. There had long been a belief that the Lausen well was fed by a large subterranean connection with the brook in the Fürler valley, and this brook ran near a peasant's house where the typhoid fever cases occurred, and was known to have been freely polluted by the excreta of these patients. The belief that an underground connection existed was based on observations which had been made ten years before, when, without any known reason, there had suddenly appeared near the brook in the Fürler valley below the hamlet a hole, about eight feet deep and three feet in diameter, at the bottom of which clear water was flowing. As an experiment, the water of the brook was turned into this hole, with the result that it all disappeared underground, while an hour or two later the public fountains at Lausen, which, on account of the dry weather prevailing at that time, were barely running, had begun flowing abundantly. They continued to flow until the Furler brook was returned to its original bed and the hole had been filled up; but every year afterward, whenever the meadows below the site of the hole were overflowed by the waters of the brook, the Lausen fountains began to flow more freely. In 1872, just before the epidemic, the meadows had overflowed just at the time when the brook had been infected by the excrements of the typhoid patients, and about three weeks after this overflow the disease broke out in Lausen.

In order to make matters more certain, however, experiments were made by putting salt into the hole referred to, whereupon, soon after, the water in Lausen gave a strong reaction for chlorine. In another experiment 5000 lbs. of flour were put into the hole, but no starch grains appeared in the Lausen water, and apparently they were filtered out in the ground. Although these comparatively large particles were not found in the Lausen well water, there is every reason to believe that the much more minute germs of typhoid fever found their way underground through the hill to the well in the Lausen valley."

The Basingstoke Epidemic. An interesting example of a typhoid outbreak due to the infection of a well in a limestone region is that of Basingstoke, England, in September, 1905.

Basingstoke is a borough of about 10,000 inhabitants in the valley of the river Lodden, a tributary of the Thames, and is built wholly on the chalk foundation.

The water-supply was taken from two wells, 10 feet in diameter, and about 30 feet deep. From one of them a heading, 96 feet wide and 9.5 feet high, was driven horizontally into the chalk over a hundred feet, branching as a Y. A vertical section of the ground at the well showed three horizontal bands of flints in the chalk, and near the bottom of the well was a fissure, through which most of the water entered the wells. The two wells were connected by a heading, which was continued on the other side of the second well.

At various times a sudden turbidity of the well water after rains had shown that subsoil water was finding its way through the chalk, and this subsoil water, coming from the low-lying parts of the town, was badly contaminated.

The epidemic began on September 18, 1905, and continued through October, during which time there were 164 cases and 13 deaths. The explosive character of this epidemic was notable. It began about three weeks after there had been a heavy down-pour of rain (August 27), — an interval long enough to allow for the passage of surface water through the soil to the well, and for the incubation of the disease.

That the subsoil was polluted in the vicinity of the well was made evident by a study of the local surroundings by Dr. Farrar, from whose report these data are taken. "Work on the main sewers was in progress in adjacent streets, and the trenches became filled with water contaminated by defective sewer connections. There was also a stoppage of a sewer and an overflow of sewage due to the failure to remove a certain plug after making some repairs, and this point of overflow was not over 150 feet from the town wells. The chances for the contamination of the well water were therefore great."

Although contamination of the water at this time was proven, the investigation failed to disclose the particular case of typhoid fever which infected the sewage.

As soon as it had been made clear that the outbreak was due to the well water, the fissure referred to was plugged up, and the reservoir and city mains were disinfected with chloride of lime.

The Newport Outbreak. A well in Newport, R. I., caused a typhoid outbreak in September and October, 1900, which was carefully studied by Professor C. E. A. Winslow. Of the 80 or more persons who fell ill during these two months, the greater part lived within a radius of 300 feet of the well, and used the well water. The well was an ordinary shallow well, 10 feet deep and 8 feet in diameter, with sides of loose stone and a cover of planking, upon which those who used the water stood while operating the wooden pump. The land tributary to this well included some twenty privy vaults within 400 feet, the nearest being only 25 feet distant. The water level in the well was only 2 feet below the surface of the ground.

It appeared that on August 31, 1900, there had been a case of typhoid fever in a house which had a privy vault 200 feet from the well, and that, on September 3, there was another case in a house 300 feet away. It was found also that the excreta from a typhoid patient found access to the privy vault which was only 25 feet from the well. The well water, therefore, had abundant opportunity to become infected, either by droppings at the top of the well, or, as Professor Winslow thought, by infected water leaching from the privies through the ground.

The Auxerre Epidemic. Another instance of subsurface pollution of a ground water which produced a typhoid epidemic was that of Auxerre, France, which has been described by Count Max le Couppey de la Forest. In May, 1902, an epidemic broke out in this community, during the course of which there were upwards of 300 cases. The water-supply was taken from a collecting gallery near the Yonne River. This gallery was located in permeable gravel, and was only 15 to 25 feet distant from a canal which had been recently dug, and which carried the water of a neighboring brook parallel to the gallery for a distance of about 250 feet. It seems that this brook water had become infected from a case of typhoid fever which occurred near its banks in April. The brook originally flowed in an old ditch alongside of a road, and, in the course of time, this ditch had become silted up, and its sides presumably rendered thereby impermeable. So long as this condition remained, no trouble was experienced, even though cases of typhoid fever had occurred on the brook before. It was not until the new channel was dug that noticeable contamination of the water in the infiltration gallery took place.

Tests were made by putting fluorescene, or uranine, into the water of the stream, and after a few hours the characteristic green color of this chemical was noticed at the pumps of the waterworks. It must, therefore, have traversed the permeable soil for a distance of 28 feet horizontally, and 3½ feet downwards, at the rate of about 12 feet an hour. Quantitative determinations showed that in all probability the water of the brook furnished one thirteenth of the supply of the gallery.

The Trenton Outbreak. Sanitarians believe, and with good reason, that most wells that become infected receive the infectious matter at the top rather than through the ground, that is, by the direct access of fecal matter through the well covering or by the inflow of surface water at times of rain. Wells in limestone regions, or in clay beds, where crevices abound, or wells in coarse gravel soils may become infected by the passage of typhoid bacilli through the soil, but in sandy soil, where the opportunities for natural filtration are good, this danger is far less, unless privies, cesspools or sewers are quite near the well.

That a well water may become infected by the passage of typhoid bacilli through the soil for a long distance was shown by some interesting investigations made by Professor Earle B. Phelps at Trenton, N.J., where an epidemic occurred, in June and July, 1907, at the State Hospital for the Insane.

The well, or spring, which gave rise to the outbreak was 20 feet in diameter and only 10 feet deep, and was located 300 feet from the highway, with the well curb 18 feet and the bottom 28 feet below street grade. This water was pumped to the buildings, but it furnished only a part of the supply, the remainder being taken from driven wells. The hospital sewer, an 8-inch tile drain, passed down the highway mentioned.

A few cases of typhoid fever occurred in April, 1907, and a few more in May. During June a number of new cases appeared, and in July there were 52 cases in the men's wards, 10 in the women's wards, and a number of others outside the grounds. Altogether there were about 90 cases.

On June 16 it was learned that the highway in the sewer was choked up and overflowing at one of the manholes, and this led to the discontinuance of the use of the well water. Studies were thereupon made to ascertain whether or not this stoppage of the sewer had any connection with the contamination of the well water, which analysis showed to be very serious. Various tests were made which showed beyond question that the sewage found its way from the street to the well through the ground. A plug was put in the sewer so as to back up the sewage in the highway near the well, while measurements were made of the quantity of water entering the well. The results showed a decided increase of inflow under these conditions. Coloring matters of various kinds were put into the sewage, and later they appeared in the well. Proof of contamination could scarcely be stronger. Bacteriological examination also gave confirmatory results.

The hydraulic studies showed that the flow of sewage to the spring was large and rapid, — so much so that it seemed certain that the flow was not one of simple percolation through soil, but rather a flow through fissures and cracks.

This instance is instructive, as it reveals the uncertainties of soil purification and the existence of unsuspected crevices and cracks. While soil, under favorable conditions, may protect a well from pollution, the only safe rule is to avoid pollution, and to make sure that the well is outside the circle of influence of cesspool, sewer or privy.

The Mount Savage Outbreak. Wells and springs on hillsides are especially liable to infection, particularly in limestone regions or where the soil is clayey. An instance of this side-hill pollution occurred at Mount Savage, Md., in 1904. This was a small mining town on the Potomac River watershed. Through it ran a small stream, known as Jenning's Run, which was grossly contaminated with fecal matter and also heavily polluted with acid wastes from the mines. In July and August an outbreak of typhoid fever occurred during which about 120 were made ill. Most of the cases were among the employees at a brickyard. The following were the facts appertaining to the cause of the outbreak.

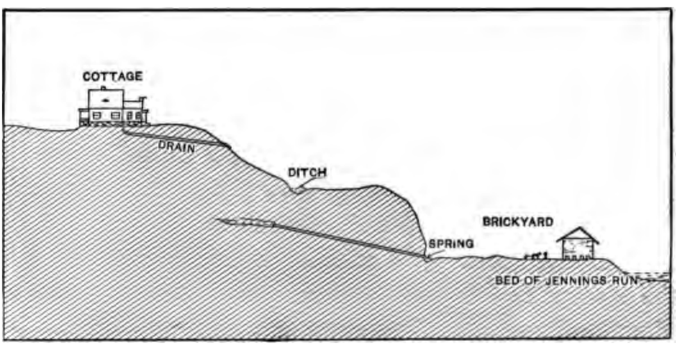


FIG. 20.

Diagram Showing the Way in Which the Brickyard Spring Became Contaminated at Mount Savage, Md. (After Parker.)

On July 4, 1904, a woman who had been nursing a typhoid patient in another town and who had just returned to Mount Savage came down with the disease. She lived in a cottage about 300 feet above the brickyard, on a steep incline that forms the north bank of Jenning's Run. The drainage of this cottage was conveyed through an iron pipe which emerged from the ground about 50 feet down the hillside and just above a ditch that received part of the drainage. This ditch went along the side of a road which passed over a bank of fire-clay. At the bottom of the fire-clay bank was a spring which furnished an abundant supply of clear, cool and supposedly safe water, and which was used by nearly all of the 200 employees of the brickyard. The relative positions of the cottage and spring are shown in Fig. 20, taken from an abstract of Dr. M. L. Price's report prepared by Horatio N. Parker.

Heavy rains occurred during the first week of July, which in all probability washed infectious matter down the hillside from the end of the house drain to the open ditch, and then through the ground to the spring. On July 11, one week after the arrival of the typhoid patient at the cottage, twenty workmen at the brickyard were taken ill, and new cases occurred daily for a week or two. Dr. Murray, the company's physician, suspected the spring at the very beginning, and posted a notice directing its disuse. This warning was not heeded, however, so that on July 25 the doctor destroyed the spring by filling it with ashes and fire-clay to a depth of several feet. This checked the outbreak. Various sanitary measures were taken to prevent the spread of the disease. Other springs and wells were either closed or rendered undrinkable by putting in alum or copper sulphate, privies were cleaned, and a vigorous campaign of disinfection undertaken, which seems to have been successful in preventing a general epidemic.

It is believed that this outbreak at Mount Savage caused an infection of the Potomac River water in the city of Washington, 185 miles down stream, where there was an unusual increase in the number of deaths from typhoid fever during September. If this were true,— and the figures seem to indicate that it was true,— the typhoid fever bacilli must have successfully passed down the acid waters of Jenning's Run and Will's Creek, down the Potomac River for 185 miles, and through the reservoirs into the service pipes. The filter plant was not then in use.

Epidemics Due to Contagion, to Flies, Etc.

The Outbreak at the New Haven County Jail. In the autumn of 1904 a typhoid outbreak occurred in the New Haven County Jail. Out of 256 prisoners there confined, 20 were attacked between October 6 and November 15. A study of the situation by Professor H. E. Smith and Mr. Edward Mahl resulted in the exoneration of the water-supply and the milk-supply. They found that on the street adjoining the jail there were five dwellings in which cases of typhoid had occurred between August 22 and September 17. The privies in the rear of these houses were in a very filthy condition, and in several instances fecal matter was found lying exposed on the surface of the ground. The food furnished to the prisoners was prepared at the jail, and often exposed on tables in front of open windows which were not screened. Flies were abundant at the time, and it is a well-known fact that at that season of the year they seek the warmth of houses. The investigators concluded that the outbreak was due to the transfer of infectious matter by flies from the privies to the food furnished the prisoners.

The Winnipeg Epidemic. The city of Winnipeg, Manitoba, the principal city of middle Canada, has been

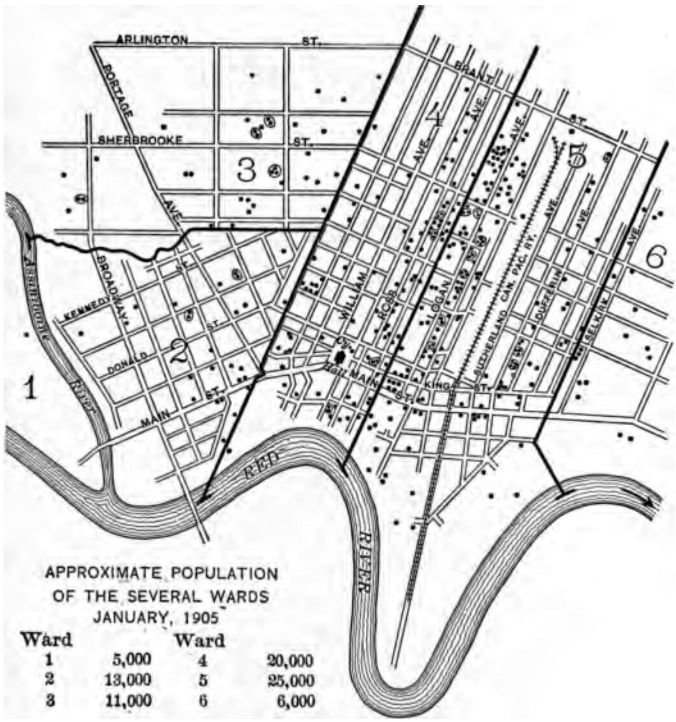


FIG. 21.

Winnipeg, Manitoba. Location of Typhoid Cases during August and September, 1904.

recently growing at a very rapid rate. Its population was 44,800 at the time of the last Canadian census in

1901; in 1907 it was estimated as 110,000. The result of this growth, while of great commercial benefit, has been to make more difficult the problems of sanitation. Neither the waterworks system nor the sewer system has been able to keep pace with the population, and the result has been that in some sections of the city there are many houses which have no sewer connections, but depend upon privies, which in this cold climate it is difficult to maintain in good condition.

For a number of years typhoid fever had been prevalent in the city, but in 1904 it suddenly increased, — so much so that Dr. E. O. Jordan was sent for to investigate the cause of the outbreak. The data given are quoted from his report. The new cases developed as follows:

Week Ending —	Number of New Cases.	Week Ending —	Number of New Cases.
1904.		1904.	
July 10	10	October 23	32
17	6	31	55
24	6		
31	4	November 6	55
		13	41
August 8	11	20	29
15	23	27	25
21	44		
28	41	December 4	39
		11	27
September 4	41	18	25
11	47	25	18
18	60		
25	65	1905.	
		January 1	27
October 2	41	9	43
9	51	15	77
16	51		

These figures really include three separate outbreaks. The first, starting in August, 1904, increased slowly until the latter part of September, and then fell off somewhat

FIG. 22.

Winnipeg, Manitoba. Location of Typhoid Cases during October, November and December, 1904.

rapidly as cool weather came on. The cases during this period were confined almost exclusively to the poorer sections of the city, and were evidently due to direct contact and to fly transmission.

The second outbreak began in October, 1904, and was a short and sharp attack. The third began in January, 1905, and was even more severe. These later outbreaks in both cases followed immediately after the temporary pumping of water from an abandoned source, the Assiniboine River, to supply a lack of water for fire purposes. This water was contaminated, although the regular supply of the city was of excellent quality, being taken from driven wells. The dates of pumping the Assiniboine water were October 10 and December 26. Most of the cases were located, not in the poorer sections, as before, but in a fine residential district, contiguous to the location of the old Assiniboine Pumping Station. It is supposed also, that during the latter part of 1904 there was a slight outbreak due to infected milk.

Epidemics in Military Camps. Typhoid fever has been the great scourge of our army camps, and it has always been easier for our soldiers to withstand bullet and bayonet than to guard against the ravages of the insidious bacillus. That this was so in early days was due to ignorance; that it has been so in recent days has been due to gross carelessness; if it continues to be so in the future, "criminal" may not be too strong a word.

It is said that during our Civil War, in the two years 1862–63, over 7000 deaths from typhoid fever occurred among the 460,000 troops in the Atlantic Region. In the British South African war there were 8000 typhoid deaths among 230,000 men. At Bloomfontein during the months of March, April and May there were 4667 cases and 891 deaths among 40,000 troops. During the Spanish War of 1898, among 107,973 troops quartered in our army camps, there occurred 20,738 supposed cases of typhoid fever, and 1580 deaths, — these typhoid victims constituting 86 per cent of all those who died from disease. This typhoid death-rate is appalling. It amounted to 1463 per 100,000, and the records did not cover a whole year, but only the summer months. If this figure is compared with the average annual death-rate for the cities of the United States, i.e. 35 per 100,000, the enormity of the epidemic may be appreciated.

The commission appointed to investigate the cause of the epidemics in the various camps concluded that the transmission of the disease was due not to water or to food, but rather to direct transmission by personal contact, to the agency of flies, and perhaps to the spread of dried fecal matter through the air as dust. The fifty-seven general statements and conclusions of their report as given in the appendix are worthy of careful study.

That typhoid fever need not decimate our fighting forces has been demonstrated by our own navy during the Spanish War, by our army in the Philippines, and by the Japanese army during its war with Russia. It is also shown by the very favorable typhoid statistics for the Panama Canal Zone.

In the Spanish War, in the North Atlantic squadron, out of 26,100 men there was not a single death from typhoid fever, and only 12 cases during the entire period of service amounting to 114 days.

Panama. During the year 1906 there were 62 deaths from typhoid fever in Panama, Colon and the Canal Zone. The average population during this year was about 66,000, hence the death-rate was 94 per 100,000. During 1907 the population has increased to over 100,000, but the death-rate has been substantially the same. This rate is, of course, not low, but when all the unfavorable conditions are taken into account it is remarkable that there has been no serious epidemic from typhoid fever among the thousands of laborers there employed. The work of Col. W. C. Gorgas, the Chief Sanitary Officer of the Isthmian Commission, and his associates cannot be too highly commended.

Japanese Russian War. In the Japanese army it is said that there was very little typhoid fever during the war with Russia. Major Charles Lynch of the General Staff United States Army has kindly furnished the following figures, which, though incomplete, serve to give a general idea of the situation:

Strength of the Japanese army	1,220,000
Number killed in battle or died of wounds	58,887
Number died of disease (14 months)	27,158
Cases of typhoid treated at the Hiroshira hospital from July 12, 1904, to September 15, 1905	1,567
Death from typhoid in the same	299
Cases of typhoid treated in the field in the second army, January, 1904, to April, 1905	104
Cases treated in the Tokio hospital, in 1904	89

These data show that typhoid fever was less abundant in the Japanese army during the war than in many American cities. Major Lynch, who was with the Japanese army, says that the disease was very rare. The troops did suffer severely, however, from other diseases, and in particular from beri-beri.

What was it that made Japan succeed in keeping typhoid fever away from her armies, while the United

States failed so ignominiously? Major Louis Seaman says that it was because of the care to secure pure drinking water and to properly dispose of fecal matter, and because of the campaign waged against flies. In his "Real Triumph of Japan," he tells of the attention paid to the burial of all stable manure, to the destruction of garbage and the general elimination of breeding places of flies; and he graphically depicts the little Japanese soldiers turning themselves into an army of fly-catchers, with ingenious devices for catching them. Apparently the soldiers had been taught to realize that the catching of flies was as much an act of patriotism as the shooting of a Russian. Whether or not this be exaggeration, and whether or not the Japanese privates understood what sanitary science meant, one thing seems certain, namely, that the Japanese officers understood the value of taking proper sanitary precautions, were quick to discover how to put principles into practice, and were firm in enforcing obedience to the orders of the medical officers.

Another important reason for the absence of typhoid fever was that the army was almost constantly on the move. They did not stay long enough in one place for camp infection to do its fatal work. It has been universal experience that a moving army is healthier than an army at rest.

Epidemics Due to Infected Milk.

The Somerville Outbreak. Between August 20 and September 10, 1892, an outbreak of typhoid fever occurred in Somerville, Mass., which was studied by

Professor Sedgwick. Among the 32 cases which occurred, 30 took milk from the same milkman. Investigation showed that the farms from which the milk was derived were in excellent condition, and that no typhoid fever existed upon them. The milk was brought to the city in large shipping cans and carried to a milk-house, where the supply of one day was mixed in large metal tanks with faucets at the bottom. After mixture, the milk was drawn off in small cans for distribution to the consumers.

The milkman had two sons, one of whom had typhoid fever during and just before the outbreak. This son drove one of the milk carts, and it was his duty to wash the cans. In all probability he did other work also around the milk-house, although his brother, who did not take the disease, was said to look after the mixing. A few of this milkman's customers were supplied with milk direct from the farms, which had not been sent to the milk-house, and no typhoid fever developed among these. The evidence went to show that the infection occurred in some way at the milk-house.

The Springfield Outbreak of 1892. In July and August, 1892, an outbreak of typhoid fever occurred at Springfield, Mass., which resulted in 150 cases and 25 deaths. This epidemic was studied by Professor Wm. T. Sedgwick and Dr. W. H. Chapin. Nearly all of the cases occurred among the takers of milk from a single milkman. Part of his milk was obtained from a farm in Agawam. It seems that in the spring of that year the farmer's daughter had had an attack of "bilious fever," while there had been other cases of "slow fever" on the place, and, in all probability, all of these cases were really typhoid fever.

It was learned that the farmer was in the habit of cooling his milk by lowering the cans into a well adjoining the cow-yard, and furthermore, that he used to submerge his cans and let them sink to the bottom, where they would be covered with from two to four feet of water. There the morning milk stood all day and the night milk all the evening. Out of the nine cans examined, four were found to leak around the stopper, and none of them were quite full when they were put into the well. As a natural consequence, the cans filled with water when submerged.

The well was an ordinary shallow dug well, covered with loose planks. The cans were lowered into the well by means of a rope, which passed through a hole in one of the planks and was secured with a knot. There was also a pump in the well. Opportunities for the pollution of the well water by substances falling between the planks were good, and, in fact, at the time when the place was examined, clumps of manure were found on the planks. The infection of the well water was thought to have occurred in the following way.

"The excreta of the patients went into the privy without disinfection, and the contents of the privy, shortly before the outbreak in Springfield, had been spread upon a tobacco field through which the workmen frequently passed to the well to get water or to work about the milk. It is not difficult to believe that in doing so they may have carried upon their boots masses of fecal matter from the privy, through the field to the well, and that pieces of it fell through the cracks into the water while the men trod upon the irregular planking."

The Stamford Outbreak. A severe outbreak of typhoid fever caused by infected milk occurred in Stamford, Conn., in 1895. Between April 15 and May 28 there were 386 cases and 22 deaths, distributed as follows:

Period.	Number of Cases.	Period.	Number of Cases.
April 15–22	176	May 7–13	18
23–29	97	14–28	15
30–May 6	80		

These figures well illustrate the sudden onset of the disease characteristic of a typical milk epidemic.

The distribution of the cases according to ages is also interesting, as it shows an unusually large proportion among children, who naturally drink more milk than older people, and are therefore more exposed to infection.

Age.	Number of Cases.	Deaths.	Percentage Fatality.
0–10	134	2	1.5
10–20	92	1	1.1
20–30	87	10	11.5
30–40	44	7	15.9
40–50	19	2	10.5
Total	386	22	5.8

Of these 386 cases, 368, or 95 per cent, occurred among those who took milk from a certain dealer, or who had access to milk purchased from him. This dealer procured his milk from three producers, but it was demonstrated that the infection probably came from the premises of the milkman himself, and that it was caused by using infected water from a contaminated well to wash the cans. The original cause of the infection, however, was not discovered.

The Marlborough Outbreak. An interesting instance of the spread of typhoid fever from a creamery occurred in Marlborough, Mass., in August, 1894. There were 150 cases, 47 of which occurred on the route of a milkman who sold only skimmed milk. This milk was obtained from a creamery which received its supply from a large number of dealers. It was found that the driver of the milk-wagon had been ill with typhoid fever, and although he took to his bed after the outbreak had begun, it was thought that he had been ill with the disease for a number of weeks before that. Besides driving the milk-wagon, this man also had the handling of the milk in the creamery, and, as a number of operations were involved, the chance for infection was great.

The Waterbury Outbreak. In June, 1890, an outbreak of typhoid fever occurred in Waterbury, Conn., during which there were upwards of 50 cases, and about 12 deaths. Professor Herbert E. Smith investigated this outbreak and found that of the 50 cases, 41 took milk from the same milkman. In one case milk was purchased from a dealer who bought milk from this milkman, and in another case the patient had eaten ice cream made from milk obtained from the same source. This outbreak was traced to one of the farms which supplied milk to the dealer in question. On this farm, prior to the outbreak, there had been three cases of typhoid fever, — the farmer, his daughter, and the farm-hand. Just how the infection was conveyed to the milk was not definitely learned, as there were a number of ways in which it might have occurred. In the first place, the farm-hand milked the cows during the early part of June while ill with the disease. He was uncleanly in his habits, and some of his fecal matter is known to have been thrown upon a manure pile adjoining the barn. Most suspicion seems to have been attached to the water used on the premises for drinking and for washing the cans.

The distribution of the cases during the month was as follows:

Period.	Number of Cases.	Period.	Number of Cases.
June 8–10	3	June 21–25	10
11–15	15	26–30	6
16–20	9		

The farm-hand referred to took to his bed on June 7, and was taken to the hospital on the 9th, but for more than a week previous to this, although ill, he had kept at work and taken his usual part in the milking, handling the milk and caring for the cows.

In this outbreak, the age distribution was as follows:

Age.	Number of Cases.	Age.	Number of Cases.
1–10	9	26–30	5
11–15	14	31–35	4
16–20	13	Over 35	5
21–25	10		

These figures show a preponderance of cases among children.

The Montclair Outbreak. In 1902 a small outbreak of typhoid fever occurred in the town of Montclair, N.J., and in Bloomfield, N.J. Although this outbreak included only about 28 cases and no deaths, its cause is of much interest.

Seeking to find the explanation the health officers were baffled by the fact that no cases of sickness could be found on any of the farms supplying milk. At length it was learned that all the cases were among those customers who took pint bottles; there were no cases among those who took quart bottles. And it finally developed that there had been a case of typhoid fever, unreported to the health department, in a family that had been served daily with three pint bottles of milk. These bottles were, of course, exchanged each day, and it was found that they were not sterilized before being used for other customers, but merely rinsed and filled again with milk. There seems to be no question but that the disease was conveyed by means of these imperfectly cleaned and unsterilized bottles.

Outbreaks Due to Infected Oysters.

The Wesleyan Outbreak. The outbreak of typhoid fever which occurred in the Wesleyan University in Middletown, in October, 1894, is of especial interest, as it was one of the earliest epidemics in this country to be attributed to infected oysters. The outbreak began rather suddenly on October 20, and continued until November 9. During this time there were 25 cases of typhoid fever, of which 13 were very severe, and 4 deaths.

The outbreak was investigated by Dr. H. W. Conn, who found that the disease was contracted at a series of fraternity dinners, on October 12, the occasion being the initiation of new members. After studying the various articles of food which were served at those dinners, the only article used in common was the oysters, which were served raw on the half shell. These oysters, it was afterwards learned, came from Fairhaven, Conn., having been taken from deeper water in Long Island Sound. Before serving to the consumers, they had been allowed to lie for two or three days in the Quinnipiac River to fatten. They were placed there on October 11.

About the same time two cases of typhoid fever occurred in a house which had a private sewer that emptied into the river at a point not more than 300 feet away from these oyster beds. One of these patients died on October 21. The evidence was conclusive that the excreta from these typhoid patients passed through the sewer into the river and infected the oysters, which were served at the fraternity dinners.

In addition to the Wesleyan students who came down with the disease, a few cases developed among visiting students from other universities, while a number of those who attended the dinners also suffered from milder intestinal troubles. It is said that the number of persons who were made ill comprised 25 per cent of those who attended the dinners.

The Winchester-Southampton Outbreaks. In November, 1902, a double outbreak of typhoid fever occurred in the cities of Winchester and Southampton, England. In each place the occasion was that of the mayoral banquet; these banquets happened to take place on the same day, namely, November 10. At Winchester, out of 134 guests, 62 were made ill, and 10 of these developed well-marked cases of typhoid fever. In Southampton, out of 132 guests, 55 were made ill, and 11 developed typhoid fever. These epidemics were investigated by Dr. H. T. Bulstrode, who found that the two epidemics had a common cause, and that this common cause was the oysters furnished at the dinners, which had been obtained from the town of Emsworth. Of the 62 persons made ill at Winchester, 61 ate oysters at the banquet, and of the 55 persons made ill at Southampton, 54 ate oysters. In both places all who developed typhoid ate of the oysters.

The oysters were purchased on the same day from the same dealer, at Emsworth, and were taken from oyster ponds located near the main outfall sewer, which ponds were flooded at high water. The pollution of these ponds was inevitable from their situation. Typhoid fever had been present for some time at Emsworth, and there seemed little doubt that the outbreaks referred to were caused in the manner indicated.

The Lawrence Outbreak. In the fall of 1904 an outbreak of typhoid fever occurred at Lawrence, Long Island, a village near the famous summer resort of Far Rockaway. Between June and December, 31 cases were known to have occurred, but, in all probability, the total number was larger than this. There were three deaths. The outbreak was investigated by Dr. George A. Soper, who found that it was caused by the eating of oysters taken from Jamaica Bay near the outlet of certain sewers, where the opportunities for infection were great. It was found that of the 31 cases, 17 had either eaten raw oysters or handled their fresh shells.

Outbreaks Due to Infected Fruit and Vegetables.

The Springfield Outbreak of 1905. During the summer of 1905 an interesting typhoid outbreak occurred in Springfield, Mass., due to a cause which up to that time had not been well recognized, namely, infected fruit and vegetables.

The epidemic began about the middle of July. 16 cases occurred between the 15th and the 28th in the poorer section of the city, where there was a large foreign population, — Jews, Russians, Syrians, etc. It was learned that most of those who contracted the disease at this time took vegetables from one man, whose wife had been ill for some time with a "slow fever." After this first crop of cases there was a slight intermission, but early in August new cases began to appear, this time among the better classes of the city, and these continued through the month and well into September, until by the end of the month there had been nearly 150 cases. Among the foreigners who first contracted the disease there were a number of venders who sold fruit, vegetables and bakery stuff through the streets from hand-carts, and it was found that these venders delivered goods to many of those who afterwards took the disease. A good many of the later cases, however, were apparently due to personal contagion, as the sanitary conditions among the foreigners referred to were very bad.

Outbreaks Due to Infected Ice.

The Ogdensburg Outbreak. There is no authentic case on record where a large typhoid fever epidemic has been caused by infected ice. There have been a few instances where a small number of cases have been thought to have been so caused, and there have been other cases where milder intestinal disorders have been attributed to ice, but in nearly all of these instances the evidence has been weak.

One of the most important cases was that of the St. Lawrence State Hospital at Ogdensburg, N.Y., in 1902, when 39 cases of typhoid fever occurred. The ice there used was unquestionably contaminated, and in all probability infected with fecal matter from typhoid fever patients. Lumps of dirt were found frozen into the ice, and it is alleged that typhoid bacilli also were found.

Another outbreak often cited is that of the military fort at Rennes, France, in 1895, where eight officers who had drunk champagne mixed with iced water, were taken ill, the ice having been taken from a contaminated source.

Outbreaks Due to Miscellaneous Causes.

Without doubt all the ways by which typhoid fever is conveyed from one person to another have not been found out. Each year some new discovery is made. Cases are on record where the germs have been conveyed by various foods. Among these are the Williams College outbreak, due to cream; the Port Deposit, Md., outbreak, due to ice cream infected from the hands of the man who made it; the Lambeth and Hackney, England, outbreaks, due to water-cresses; the Jersey City case, attributed to infected celery; the South-end, London, outbreak, due to cockles. It is singular that no outbreak has been traced to food from bakeries, restaurants, or hotels, or to candy or soda water. There seems to be no reason why any article of food which comes in contact with the hands of those making or selling it may not be a vehicle of infection.

Special Characteristics of Epidemics.

The various epidemics and outbreaks which have been described are alike in some respects, but each one has some distinctive feature.

Looking at the various epidemics due to infected water, it will be noticed that in those cases where river water was subject to constant pollution, the disease increased rather slowly and did not reach its maximum for a number of weeks, after which it slowly subsided; while in those cases where the water became suddenly infected, the disease broke out violently at the start, and sometimes came as a series of blows, — one after the other. Outbreaks due to milk, oysters, etc., also occur with explosive violence. In epidemics due to contagion, however, the onset is likely to be more gradual. All epidemics, however, decrease slowly, and many cases continue to occur for a long time after the full force of the blow has spent itself. This is because of the secondary cases due to direct contact with the primary cases. Water epidemics generally cover longer periods than outbreaks due to milk, oysters, etc. These distinctions should not be too sharply drawn, but an understanding of the general tendencies will sometimes be of service in tracing the

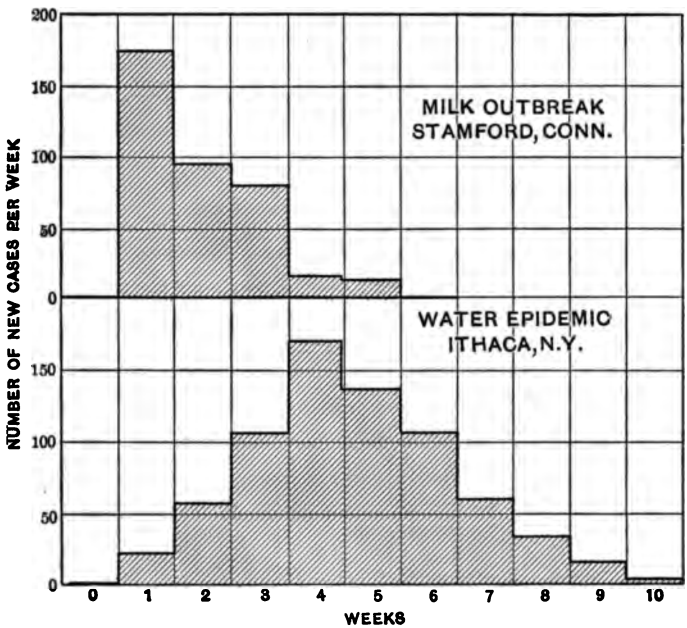


FIG. 23.

Diagram Showing Two Types of Epidemics.

origin of an outbreak. The following curves represent rather exaggerated cases of two of these types of epidemics.

Attempts have been made to establish a relation between the intensity of infection and the severity of the disease, but generally without much success. In outbreaks due to milk or oysters, one would naturally expect the infection to be severe, the dose of bacilli to be larger, and, in consequence, the disease to be more violent, or the period of incubation shorter. To a certain extent this is true, but in all probability the severity of the fever depends more upon the constitution of the persons infected than the intensity of the infection. Yet one may readily conceive how typhoid bacilli might retain a greater degree of vitality, and presumably of virulence, in such a good culture medium as milk than in an unfavorable medium like water. There may be also different "strains" of the bacillus, — some of which are more virulent than others, — but such speculation as this carries us beyond the known facts of science. There is some reason to believe, however, that the incubation period is shorter and more uniform in the case of intense infections due to milk or to direct contact than in the case of the water-borne type of the disease, when the attenuation of the bacteria is often greater.

Warnings. It is a familiar saying that "Coming events cast their shadows before." This is very true of typhoid fever epidemics, although not universally true. It has happened on many occasions that an outbreak of typhoid fever has been preceded by an unusual prevalence of diarrheal troubles, — winter cholera, etc. Examples of this have been already referred to. These milder disturbances have a shorter period of incubation than typhoid fever, hence they are manifested earlier. Thus, within a day or two after the mayoral banquets at Winchester and Southampton many of the guests were taken ill with intestinal troubles, but the typhoid fever did not develop for ten days or so. So also in the case of the steamer "Northwest." The prevalence of diarrheal diseases in any community, especially during the winter, should be regarded therefore as a warning of an impending calamity.

One of the best illustrations of the sequence of typhoid fever, with its comparatively long incubation period, and intestinal diseases which make a more sudden attack, is that of Hamburg, Germany, during the cholera epidemic of 1892–93. The following figures show the morbidity for these two diseases.

Week Ending —		Cases of Cholera.	Cases of Typhoid Fever.
	1892.		
August	20	115	42
	27	3593	38
September	3	6157	69
	10	3217	139
	17	2092	155
	24	1224	132
October	8	101	76
	15	41	52
	22	14	43
	29	1	34
November	5	3	32
	12	5	21
	20	4	15
	27	3	14

Infection Widespread. The question is often asked, "Where does the original infection come from?" Sometimes in an outbreak this can be traced; more often it cannot. But a few moments' thought will show that there is no lack of supply of typhoid fever in the United States. Suppose the average death-rate from this disease throughout the cities of the country to be 35 per 100,000. That means at least 350 *cases* per 100,000 per year, — or, say, one case each year to every 250 or 300 persons. In many rural districts the disease is even more prevalent than this. Such being the case, there are sure to be some cases of typhoid fever among the thousands of farmers who send milk to the great cities, and who handle the other food supplies. The sewage of all large cities certainly contains the typhoid bacillus at some time in the year. Then there are the "typhoid carriers" and the resistant typhoid cells that are long lived and that may exist for months in the contents of a privy or cesspool, or in the mud at the bottom of a stream behind some dam. When all these facts are taken into consideration, the wonder is not that there is so much typhoid fever, but that there is so little.

Many more epidemics might be referred to, and doubtless better examples than those cited might have been picked out, — but enough have been given to illustrate the main sources of infection. In some cities supplied with impure water, there is a constant succession of epidemics, — a new infection occurring before the last has loosened its hold. And all over the country miniature outbreaks are occurring by the hundred. Few of them reach a place where they attract other than local attention; no serious attempt is made to ascertain their origin, — and so they would go on, widening their circle of influence, were it not for the checks imposed by sanitary science.

Epidemics as Life Savers. Strange as it may seem, the great epidemics have done more than almost anything else to reduce the typhoid death-rate of the country, for, by reason of their severity, they have imperatively demanded that their cause be ascertained and prevented. They have stimulated research, enlightened the public as to the principles of sanitary science, and compelled city officials to apply these principles for the good of the people. They have aroused careless cities to the need of a pure water-supply; caused laws to be passed preventing the sale of oysters fed near the sewers; and increased the vigilance of milk inspection. They have awakened physicians, and citizens as well, to the sense of their public responsibilities in a way that the constant presence of a high death-rate will never do.

These epidemics are usually set forth as terrible scourges, — and so they are, locally considered, — but they influence the general death-rate of the country very little. Or, mathematically expressed, a very high death-rate applied to a small population causes fewer deaths than a moderate death-rate applied to a large population.

Thus, during the famous epidemic year in Ithaca, N.Y., in 1903, the death-rate rose to 625 per 100,000, which, applied to a population of 13,156, meant 82 deaths. During the same year the average death-rate for the state of New York was only 21.5 per 100,000, but this, applied to the total population of 7,600,000, meant 1665 deaths. The epidemic attracted attention; the moderate death-rate did not. So, too, in the Spanish War, the shameful occurrence of typhoid fever in our military camps aroused general indignation, while in the Southern states and elsewhere in the country, the rural death-rate, far more reaching in its effects and sweeping away a far greater army of victims, goes on year after year almost without comment.

CHAPTER IX.

THE INVESTIGATION AND CONTROL OF TYPHOID FEVER EPIDEMICS.

THE study and control of typhoid fever outbreaks and epidemics is naturally a function of the health authority,— the local board of health, or health officer, if there is one, or the county or state board if there is no competent local authority. The matter, however, is one which usually demands quick action and the sound judgment which comes from experience, and hence it is becoming quite common for experts to be called in to assist the local authorities or to take charge of the situation. To trace an epidemic to its source is not so much a study for the doctor as for the statistician, the detective, the bacteriologist, the chemist and the engineer. The specialist has to be all of these at once. The local physician is sometimes, but not always, equipped for the task. The expert is more likely to see the facts in their true perspective; he is also more likely to obtain the coöperative assistance of all parties interested; and he is less likely to be influenced by the confusion of ideas which often occurs when a community suddenly finds itself face to face with a scourge of unknown origin.

In taking up the investigation of an epidemic with a view to its control there are four principal things that have to be done:

First. It must be ascertained whether or not the disease is actually present, and whether it is present, as a general epidemic or merely as a local outbreak.

Second. The cause must be discovered.

Third. The cause must be removed.

Fourth. The spread of the disease must be prevented.

Collection of the Data. The local board of health, from its physicians' reports, should be the first to learn of the existence of a typhoid increase, but often the first note of warning comes from rumor or from the daily press. Of course, if the physicians fail to report, the board of health has no facts; but if the returns are made and are merely tabulated, but not studied from day to day, then the health officers have failed in their duty. In the orderly working of a health department any increase in the reported new cases of typhoid fever would lead to an immediate study of each case, and to a special inquiry among the physicians as to the presence of other suspected cases. By so doing an epidemic would often be nipped in the bud, without alarming the community. There is perhaps no place where the saying so well applies as here, that "a stitch in time saves nine."

It happens more often, perhaps, that the extent of a typhoid outbreak is unduly magnified. A reporter, seeking copy, starts a typhoid scare, and alarms the people and injures the reputation of the city.

The first thing of importance, therefore, is to find out who have the disease, where they live, and where they were taken sick. These and various other statistics are needed in tracing the epidemic to its source. The necessary data are seldom reported to the health department with sufficient completeness, and nearly always a special canvass has to be made. The names and addresses of the patients having been obtained from the health departments and from the physicians, house-to-house visits are necessary for the sake of obtaining first-hand information as to the onset of the disease, the history of the person as to the use of water, milk, food, etc., and for the sake of making a sanitary inspection of the premises.

If the epidemic is an extensive one it is convenient to record the various data on printed forms drawn up to fit the special case. The principal data required are the following, but other items will naturally suggest themselves in particular cases.

SCHEDULE OF DATA NEEDED IN THE STUDY OF TYPHOID FEVER OUTBREAKS.

Number of case (for reference)....................................
Name of patient?..
Residence?..
Physician's name and address?..................................
Date of physician's report?......................................
Character of house (private house, boarding house, apartment, hotel, etc.)?..
Age?..........................Sex?..........................
Occupation?......................Place of business?...............
Where living month previous to illness?...........................
Absence from home previous to illness?............................
If so, where?..
Date of first symptom?.................Date of taking bed?........
Date of doctor's first call?..

Date of leaving bed on recovery?........Date of relapse?............
Date of death?..
Blood examined?..........Date?..........Result?................
Spleen enlarged?..........Rose spots?............................
Sanitary condition of premises?..................................
Source of drinking water, — at home?...at business?.....Elsewhere?..
Milk supply from?..........Milk habitually drunk?...............
Raw oysters eaten?..........Source?..............................
Patient has separate room?.............Nurse?....................
Were stools disinfected?................the urine?................
Any other precaution taken?.....................................
Other cases in house? (Obtain names and dates)..................
Other cases among business associates?..........................
Schoolmates?.........................Friends?..................
Number of people in the house...................................
Remarks: ....
....
....
....
Information given by...
Information given to...
Date of information..
(Signed).....................

Study of the Data. As fast as the data are obtained they should be tabulated and studied from various points of view.

Were the cases generally distributed over the city or were they confined to one locality? A convenient method of ascertaining this is to take a street map and locate the cases with black-headed pins stuck in at the place of residence. This map, with its pins, can afterwards be photographed for record. If the cases are localized, does the locality suggest anything as to a common cause? Is it coincident with some particular water-supply, as it was in New Haven, or with some milk dealer's territory, as in Somerville? Is it located in a section where there are no sewers, as in Winnipeg? Is it around some public well, as in Newport? Or are the cases merely concentrated in one place because the population is densest there? Does the geographical distribution of the cases change as the epidemic progresses? Where were the early cases with respect to the others?

What was the probable date of infection? Was there a sudden, sharp attack, or was the onset gradual? If the latter was the case, what were the limiting dates of infection? The date of infection has to be estimated by counting back from the time when the patient was taken sick. All things considered, the safest date to count from is that of taking bed. Often this cannot be learned, especially if the investigation is made sometime afterwards. But the date of going to bed is seldom far from the time of the physician's first call, and this can usually be obtained from the doctor's memoranda. If the epidemic is believed to be due to milk, or oysters, or some other cause involving an intense form of infection, the probable date when the patient received the bacilli into his system may be obtained by counting back 7 to 10 days; but if a water infection is suspected, a period of 10 to 15 days will probably give a better estimate. It must be remembered, however, that occasionally the period of incubation may be considerably longer than this. Sometimes it is necessary to count back from the appearance of some particular symptom, and in that case the attending physician's advice should be obtained as to whether this occurred in the second or third or fourth week of the disease. Sometimes one has to figure back from the date of death. That also is something about which the attending physician should be consulted.

Were there any outbreaks of diarrhea preceding the typhoid epidemic? When and among whom did they occur?

Were most of the cases among young people and children? If so, this suggests milk as a cause. Did they all or most of them use the same water-supply, or take milk from the same dealer, or food from the same source?

Had the patients been together anywhere, at business or in school, or at some banquet?

In short, was there any common cause where eating or drinking or association might give opportunity for infection?

If the public water-supply is suspected, investigations should be carried on to determine whether or not the source is a satisfactory one, whether it was contaminated with fecal matter, and whether, finally, it was infected from some particular case. This is such a broad subject that it cannot be fully gone into here. The aid of the bacteriologist and chemist usually has to be invoked, and the interpretation of his analyses is an important matter and one where his judgment is of equal weight with the figures themselves. It must be remembered, however, that as a practical test, the bacteriologist cannot tell whether or not the typhoid bacillus is or is not present in a sample of water. He may find the colon bacillus, the intestinal germ, and that will indicate fecal pollution, *i.e.*, domestic or animal contamination, but it will not prove of itself that the water is infected. Analyses are nearly always very valuable and even necessary, but too much must not be expected of them, particularly as the samples of water are often not collected until many days after the date of infection. An inspection of the source, with particular respect to the occurrence of typhoid fever near it, is of the utmost importance.

In connection with a study of the water-supply the meteorological conditions should be taken into account, — the temperature, the rainfall, the occurrence of melting snows, floods, etc.

If the milk-supply is suspected, inspections of the various farms should be made, their sanitary conditions noted, their well-waters, — and especially the occurrence of typhoid fever, or "grippe," or "bilious fever," or "slow fever" or something that might be typhoid in masquerade, in the farmer's family or among his employees. The transportation of the milk and its distribution should be studied with reference to cleanliness and to the occurrence of the disease among those employed.

In connection with oysters it must be remembered that they may be infected at their layings, or during the process of floating, or during their handling. By far the greatest chance of infection, however, comes from the practice of floating in sewage-polluted waters.

In most cases these various investigations are not made serially, as described, but are all carried on together, and as rapidly as possible, in order to learn the cause. Sometimes an expert, because of his experience, is able to size up the situation very promptly; whereas, if left to local study, it may take a long and careful investigation. In any study of a typhoid fever outbreak one should not be led into a blind attempt to trace the disease to some well-recognized cause; for it must be remembered that science does not yet know all the means by which the germs of the disease may be spread.

The student should familiarize himself with the best methods of procedure, by a careful study of the detailed reports of several typical epidemics.

The Control of Epidemics. The control of a typhoid fever epidemic is a subject upon which little need be said, after what has gone before. Obviously there are two lines of action required — the removal of the original cause, and the prevention of the spread of the disease. The actual character of the work to be done naturally depends upon circumstances, but in a general way it consists of putting into practice the various sanitary measures that unite to form the three barriers of enclosure and the three lines of defense described in earlier chapters, — with this exception, that these lines have to be drawn more strictly than under ordinary conditions.

If the cause of the epidemic has been ascertained beyond reasonable doubt, the course to be pursued is usually clear. If the cause has not been definitely ascertained, it may be necessary to take into account one or more suspected causes, and to act in each case as though it were the real one. This naturally involves some unnecessary work, but usually the matter is so serious a one that it is not wise to take any chances or leave any stone unturned.

If a well water has been found to be infected, it is a comparatively easy matter to discontinue its use, disinfect the well and thoroughly clean it out; if a milk-supply is at fault, a thorough process of cleansing and disinfection will prevent further trouble; but if the public water-supply is found to be the cause, the situation is a far more serious one, and one which calls for the exercise of greater skill and experience. Just what to do is often a difficult matter to decide, as much depends upon whether the infection is a transient one or one that is likely to persist for some time, and whether the infected source is the only water-supply available. If a city has more than one supply it may be possible to discontinue the use of the one that is suspected as being the cause of the epidemic, and depend for a time upon the other sources. But more often, perhaps, the conditions are such that this cannot be done, and that the supply, even though infected, cannot be shut off without leaving the city without fire protection. In this case the only thing to do is to discontinue its use for drinking, as far as this can be done, and to depend upon boiling the water in those houses where no other supply can be obtained. In some cities it has been found possible to temporarily furnish the citizens with spring water, distributed without charge, or for a merely nominal charge.

In some cases efforts have been made to disinfect the entire public supply in order to render it safe. This, however, is very difficult of accomplishment, except in very small supplies; in large supplies it is practically impossible. Copper sulphate has been held up as a safe and efficient chemical to be used for this purpose, and no doubt its use in some cases would be beneficial, but there are reasons to believe that it is not an adequate remedy. Dilute solutions of copper salts will kill a large percentage of typhoid bacilli, but stronger solutions seem to be required to kill the more hardy forms which have been referred to as the "resistant minority," so that in order to completely render water sterile it would be necessary to use large quantities of copper, — quantities so large, in fact, as to be objectionable. In large supplies, furthermore, there is difficulty in applying the chemical so as to properly distribute it through the water. While disinfection of the supply might do some good, yet, taking everything into consideration, there is probably no better temporary expedient that can be adopted than to thoroughly boil the water before it is used, at the same time taking steps to decrease its use by providing for a house-to-house delivery of pure water.

Filtration of water, while an adequate remedy, cannot often be undertaken as an emergency measure, although under some conditions this might be done. It often happens, however, that a typhoid epidemic that has been caused by an infected water makes such an impression on the community that filtration, or the adoption of a new supply, soon follows.

To control an epidemic and keep it within bounds demands prompt and energetic measures. An epidemic is almost sure to bring to light any weak spots in the sanitary conditions of a city. It must be remembered that there is a difference between contamination and infection. A contaminated well water may be used for years without causing typhoid fever, but during an epidemic it may become infected as well as contaminated, as in the case of the Barnes well at Ithaca. Many other forms of uncleanliness which ordinarily cause no serious trouble may, at a time of an epidemic, be the means of spreading the disease. Hence, the presence of typhoid fever in epidemic form in a community demands not only the removal of the orignal cause, but a wholesale house cleaning, and the institution of far-reaching sanitary reforms.

Besides taking measures to rid the city of all that might tend to spread the disease through secondary infection, it may be necessary to take extraordinary measures to secure adequate services for the sick. It may be necessary to bring in extra physicians and nurses from outside, to establish a temporary hospital for those who cannot be well treated in their homes, to supply freely large quantities of simple disinfectants, and to make many blood tests of suspected cases. During a general epidemic the importance of isolation becomes greatly increased, as the disease is likely to take greatest root among the poorer classes of population where contagion cannot be easily prevented. Hence the question of hospital service at such times becomes one of paramount importance. The board of health should have the power to remove patients to the hospital if they cannot be treated in their homes without danger to others.

Through it all, a "safe and sane policy" should be consistently pursued. A community afflicted with a typhoid fever epidemic is sometimes almost panic-stricken. Correspondents may fill the public press with their theories, and many foolish things may be said and done. What is needed is a strong central authority that for a time can exercise almost autocratic power, and a government and a public opinion that will uphold such authority, and provide all necessary resources. Fortunate, indeed, is the city that has a health officer or health department equipped for such an emergency and a government that will rise to the occasion.

CHAPTER X.

THE INFLUENCE OF PUBLIC WATER-SUPPLIES ON THE TYPHOID FEVER DEATH-RATES OF CITIES.

THE manner in which the sanitary quality of public water-supplies influences the typhoid fever death-rates of cities, has been sufficiently discussed. It remains to study the magnitude of this influence. The relation between the two is so close that the typhoid death-rate has been often used as an index of the quality of the water. Generally speaking, it is safe to do this; a very low death-rate indicates a pure water, and a very high rate, a contaminated water. Between the two extremes there is a range of death-rates from which the quality of the water cannot be predicted, and the aid of other data has to be invoked. But, taking the death-rates of a city for a term of years, and studying their seasonal and annual variations and their general average, one can form a pretty sound conclusion as to the sanitary quality of the public water-supply.

In his valuable little book on "Water and Public Health," published in 1897, Mr. James H. Fuertes, C. E., gave a series of diagrams in which the relation between typhoid death-rates and various water-supplies, grouped according to the character of their source, was strikingly shown. These diagrams, although based upon data ten years old, are just as applicable to-day as they were then. One of them is reproduced in Fig. 24. It shows the range within which 75 per cent of the death-rates fell for each kind of water-supply, and may be considered as marking the ordinary limits for each group, although extreme figures both above and below those given were not uncommon.

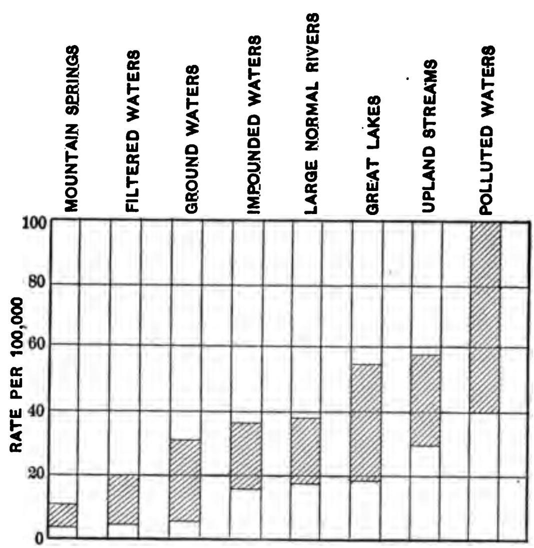


FIG. 24.

Diagram Showing the Relation between the Character of Water-supplies and Typhoid Fever Death-rates. (After Fuertes.)

Spring waters, well waters, and filtered surface waters are generally considered as safe sources of supply, and the diagram shows that for these groups the death-rates range from about 5 to 25 per 100,000, the average being somewhere between 15 and 20. Supplies from upland streams, impounding reservoirs, and from large lakes and rivers, are insecure in quality; and the corresponding death-rates range from about 15 to about 55, and average about 35 per 100,000. Supplies which are conspicuously contaminated may have death-rates anywhere from 40 up to 100 or more. No hard and fast lines can be drawn between the different groups, as the potency of other causes than water has to be considered in each case,

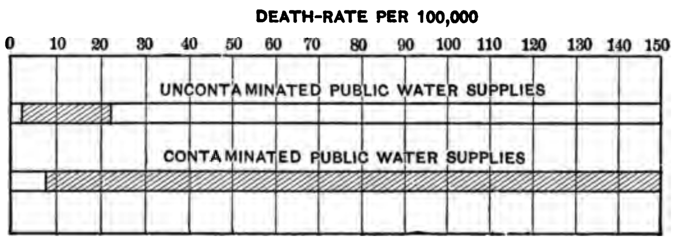


FIG. 25.

Diagram Showing the Ordinary Range of Typhoid Fever Death-rates in Cities having Contaminated and Uncontaminated Water-supplies.

but it is commonly assumed that in the northern parts of the United States a continued typhoid death-rate above 20 per 100,000 indicates that the public water-supply is of questionable purity, while a continued death-rate below 15 indicates safety. In the Southern states the dividing lines would have to be placed at a somewhat higher figure, as the influence of other factors is greater.

If a good water-supply means a low death-rate, and a bad water-supply means a high death-rate, one would expect to find that when a city changed its supply from a polluted river to that of driven wells, or constructed filters to purify a contaminated water, this would be followed by a lessened prevalence of typhoid fever. This is just what has been happening on all sides during the last two decades, and it is to improved water-supplies more than to anything else that the recent reductions in typhoid fever have been due. A few examples will sufficiently illustrate this:

Cities which have changed their Source of Supply.

Frankfort-on-the-Main, Germany. Frankfort-on-the Main introduced a public water-supply in 1872. Prior to that, there had been no general supply, and private

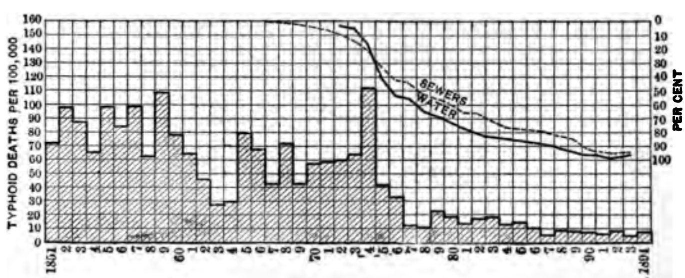


Fig. 26.

The Curves Marked "Sewers" and "Water" Show the Percentage of Houses Joined to the Sewers and Water Mains, Frankfort-on-the-Main, Germany. (After Fuertes.)

wells had been the only source. W. H. Lindley, C.E., has shown the effect of this new supply on the health of the city by a diagram (Fig. 26) which is self-explanatory.

Newark, N.J. In 1892, Newark, N.J. changed its source of water-supply from the polluted Passaic River to the Pequannock River, an upland supply, utilized by the construction of a series of large impounding reservoirs.

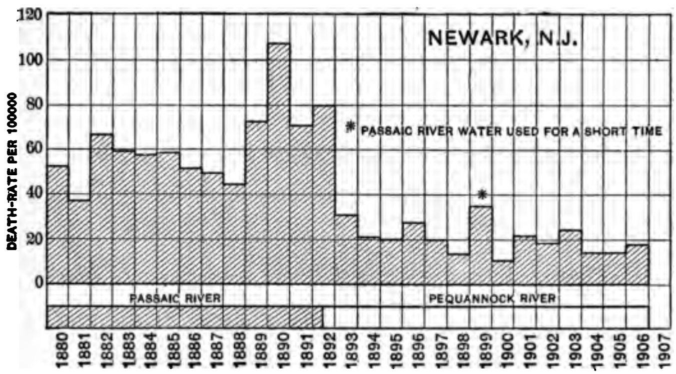


FIG. 27.

Diagram Showing the Relation between the Public Water-supply and the Typhoid Fever Death-rates in Newark, N.J.

The population on this watershed is sparse; there are no large towns on it, and the drainage of the individual houses near the tributary streams is carefully looked after. The change in the typhoid death-rate resulting from the use of this better water is shown in Fig. 27.

In February, 1899, during a spell of very cold weather, a water famine was threatened and it became necessary to augment the supply by pumping water from the old Passaic River supply into the low service system. This was done for about a week, and resulted in about four hundred cases of typhoid fever and about fifty deaths, — practically all of them within the low service district.

Jersey City. During the last ten or fifteen years Jersey City has had four different sources of water-supply. For some time prior to 1896 the water was taken from

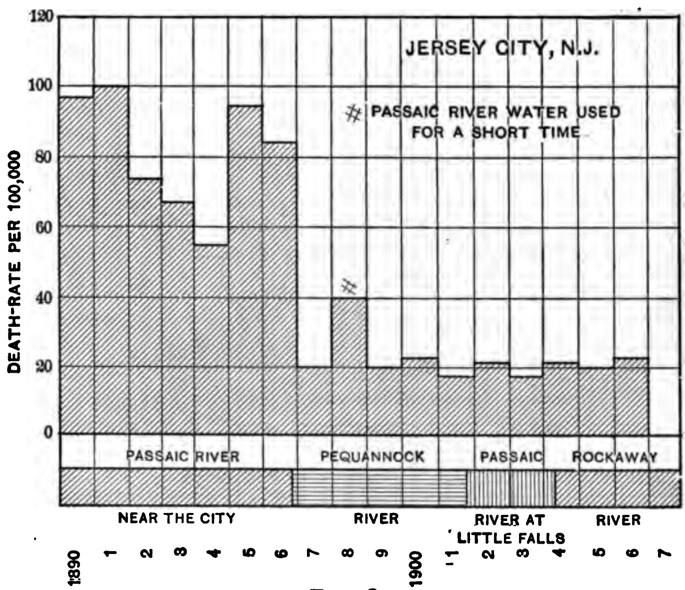


FIG. 28.

Diagram Showing the Relation between the Water-supply and the Typhoid Death-rates in Jersey City, N. J.

the Passaic River at Belleville, near the city, at a point where it was considerably polluted. Since 1896 the supply has been taken from three upland sources. Between 1896 and 1901 the Pequannock water was used; between 1901 and 1904 the supply was obtained from the

Passaic River at Little Falls. Since then, the Rockaway River water from the Boonton reservoir has been used. In no case has the water been filtered. The diagram shows that since the abandonment of the Passaic River

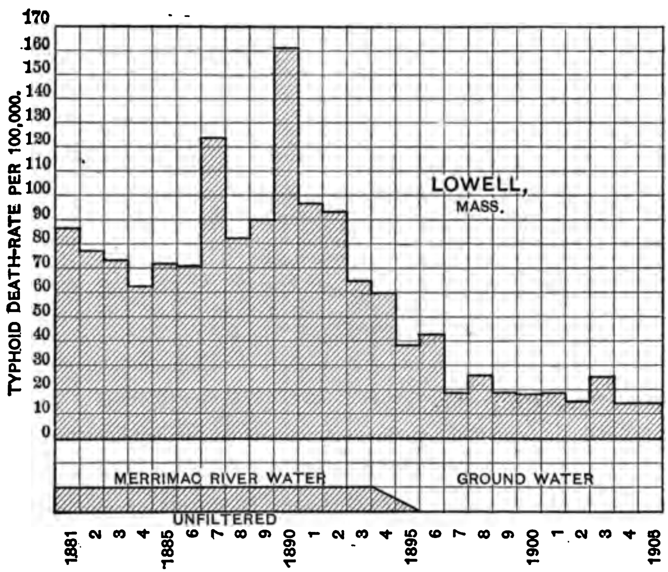


FIG. 29.

supply the typhoid fever death-rate in the city has been lower than formerly, although there was an outbreak in 1898 which was due to a temporary return to the old Passaic River supply. Except for this year the fluctuations in the typhoid fever death-rate of the city have not been large. The Rockaway source, however, is not as safe as the other upland sources, and since its use there has been a slight increase in typhoid fever in the city.

Cleveland, Ohio. The city of Cleveland takes its water-supply from Lake Erie. Prior to 1904 the point of intake was only 1.5 miles from the shore, and was subject to occasional severe contamination from the city's sewage; but in the year mentioned a new intake was put in service, and the water is now taken at a distance of four miles from the city. The change in the supply resulted in an immediate reduction in the typhoid death-rate. This has been already referred to. (See Fig. 18, p. 171.)

Lowell, Mass. Profiting by the lesson of the epidemics of 1890 and 1892, the city of Lowell, in 1896, abandoned the use of the polluted Merrimac River and obtained a supply from driven wells. The change to the new supply was somewhat gradual, and the reduction in the death-rate was correspondingly gradual.

Cities which retained their Old Supplies, but Constructed Filters.

Zurich, Switzerland. The water-supply is taken from Lake Zurich, near the outlet, not far from the heart of the city. No public sewers discharge into the lake, but the water is necessarily more or less polluted. Prior to 1886 the typhoid fever death-rate in the city had been high, but in that year new filters were constructed and this immediately reduced the rate to a low figure.

Hamburg, Germany. Hamburg is chiefly famous among sanitarians for the great cholera epidemic of 1892. At that time filters were under construction for the purification of the water-supply, which was taken from the Elbe River. The works were constructed in 1893, and since then the health of the city has greatly improved.

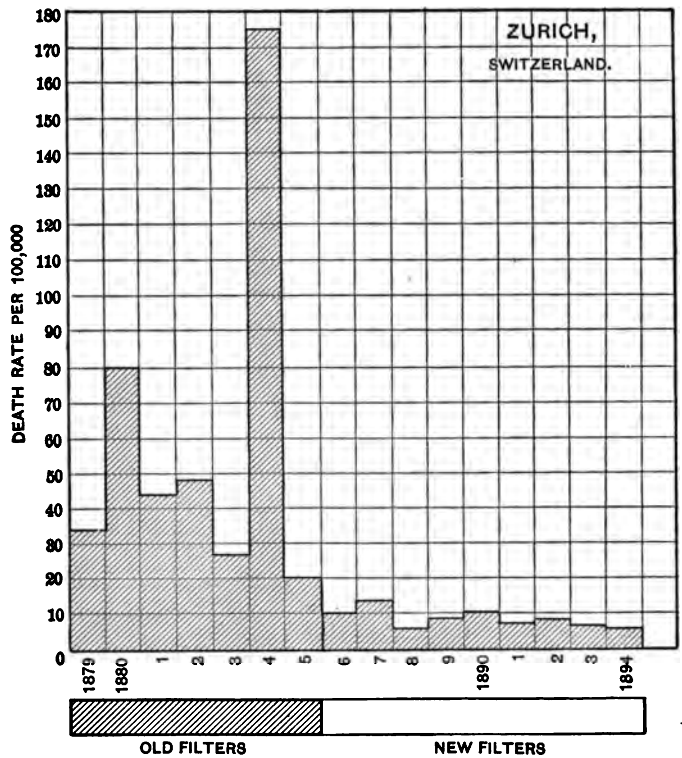


FIG. 30.

Lawrence, Mass. Taught by the sad experience of several epidemics, the city of Lawrence constructed a filter plant in 1893. This city has the distinction of being the first in this country to take up filtration

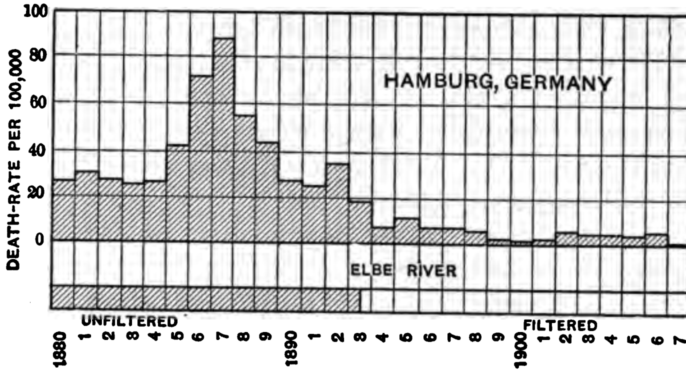


FIG. 31.

Diagram Showing the Relation between the Water-supply and the Typhoid Death-rates of Hamburg, Germany.

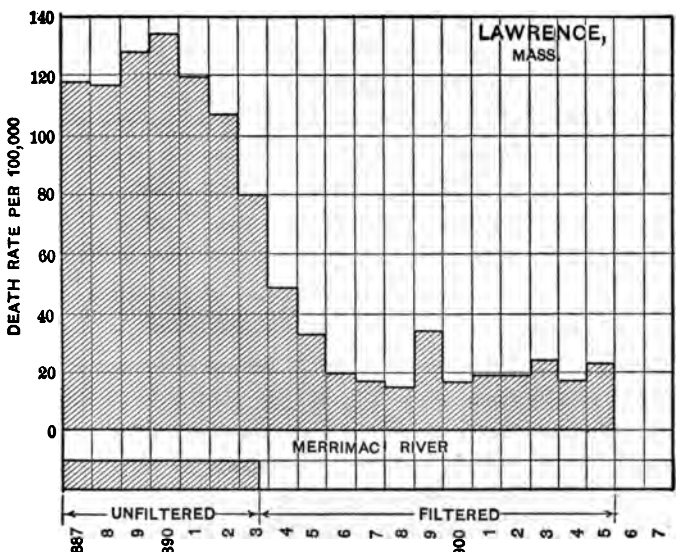


FIG. 32.

along modern lines, and the credit belongs to the Massachusetts State Board of Health. The particular type of the filter resulted from the experiments made at the world-renowned Lawrence Experiment Station, with which some of the best-known American sanitary engineers have been connected.

The construction of this filter brought an immediate reduction in the typhoid fever death-rate. The filter gradually became outgrown, however, and its efficiency correspondingly decreased. At the present time (1908) it is being enlarged.

The original Lawrence filter differed from those which have since been built. Among other things, it had no roof, and in consequence there has been more or less trouble in cleaning the sand beds in the winter on account of ice. The filter was designed also to operate intermittently instead of continuously.

Albany, N.Y. The filter at Albany, constructed in 1889 to purify the water of the Hudson River, polluted by the sewage of Troy, Cohoes, Schenectady, and many other cities, represents the type of filter which has since been largely used in this country. It followed European practice more closely than that at Lawrence. It is a "sand filter," or a "slow sand filter," as it is often called, and consists of a large area of sand four feet deep which rests on a foundation of gravel and coarse stones, embedded in which are collecting drains. This sand area, which covers 5.6 acres, is divided into several "beds," which may be separately controlled. The filter material rests on a concrete floor, and is covered with a groined arch roof, supported on piers which pass down through the sand bed. The river water, after first passing through a large settling basin,

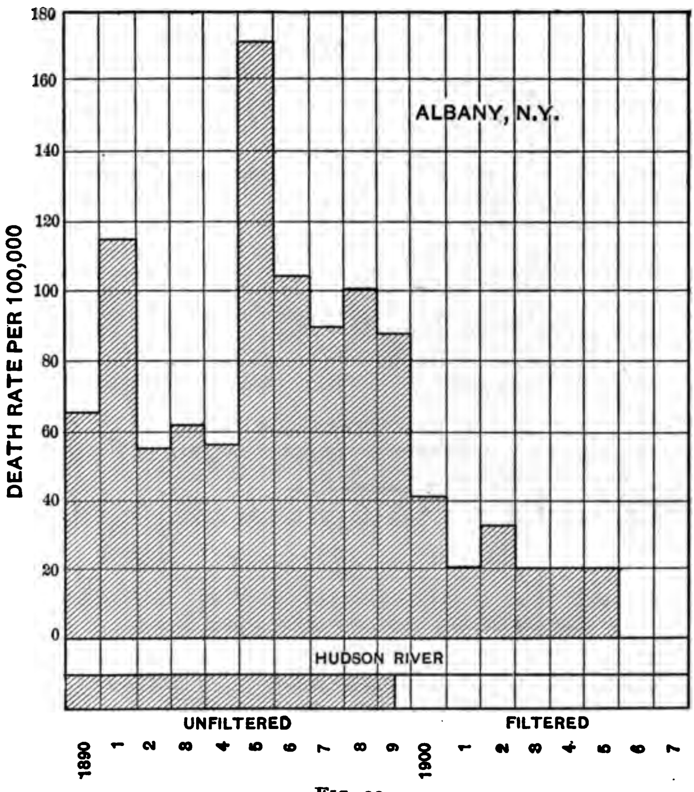


FIG. 33.

Diagram Showing the Relation between the Water-supply and the Typhoid Death-rates of Albany, N.Y.

flows over the sand, filters down through it at a slow rate, and collects in the underdrains. The process removes, on an average, something like 99 per cent of the bacteria, and any typhoid germs present are presumably removed in the same proportion.

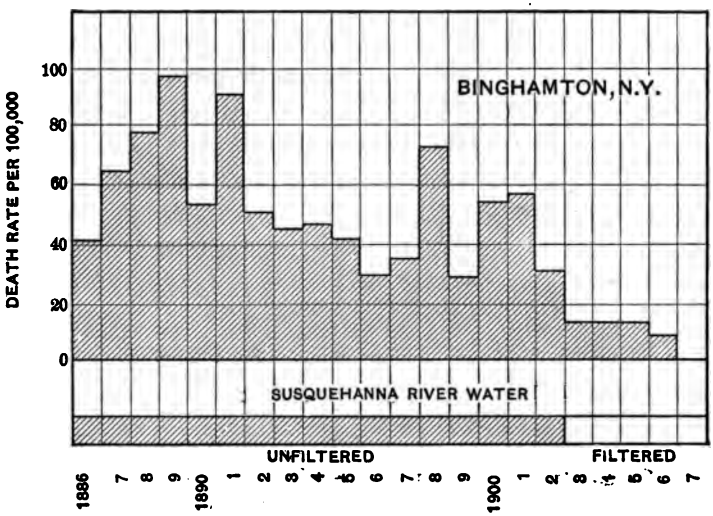


FIG. 34.

Diagram Showing the Relation between the Water-supply and the Typhoid Fever Death-rates of Binghamton, N.Y.

When the people of Albany drank the Hudson River water raw, typhoid fever was rampant; but the filter put a stop to this, and caused a very sudden drop in the death-rate. This filter is now working up to its capacity, and alterations are being made with the object of increasing its output. In considering the typhoid death-rate since 1900, it ought to be noted that the filtered Hudson River water does not furnish the entire supply of the city. Part of the water used is taken from a surface supply

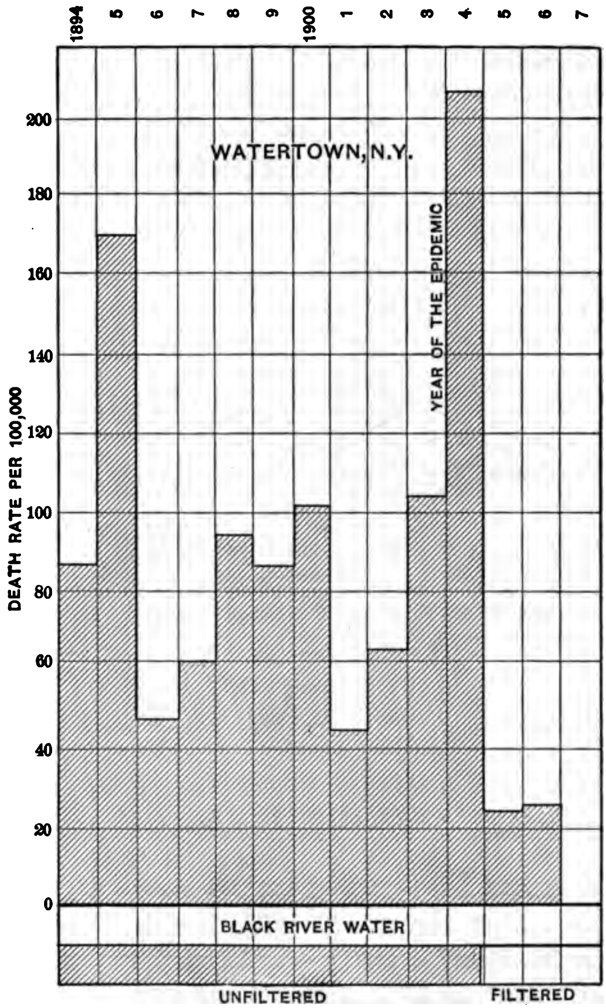


FIG. 35.

Diagram Showing the Relation between the Public Water-supply and the Typhoid Death-rates in Watertown, N.Y.

which is not filtered, and the sanitary quality of which is not secure.

Binghamton, N.Y. The water-supply of Binghamton, N.Y., is taken from the Susquehanna River and is used without any storage whatever. The water is often muddy and, worse than this, it is contaminated. In 1902 a filter plant was constructed. It is of the mechanical type, using alum as a coagulant. Almost immediately after this installation there was a decided decrease in the amount of typhoid fever, as well as of winter cholera, which up to that time had been quite prevalent. During the last four or five years the typhoid fever rate has been exceptionally low.

Watertown, N.Y. Watertown takes its water-supply from the Black River, a stream which is considerably polluted by paper-mill refuse, and with the sewage of several large communities. For many years the typhoid fever rate was high, and some years it was excessively high. During 1904 there was a severe epidemic during which about six hundred people were made ill and nearly fifty people died. A filter plant was under construction when this epidemic occurred, but it was not put in service until September, 1904. Since then the typhoid fever death-rate has been very much lower.

Paterson, N.J. Paterson, N.J., is one of a group of communities supplied with water by the East River Water Company. The source of the supply is the Passaic River at Little Falls. Until 1902, it was used without filtration, but during that year a mechanical filter was put in service, and since then the typhoid fever rate has been much lower. The other communities supplied by the same company show corresponding reductions in the typhoid fever death-rates.

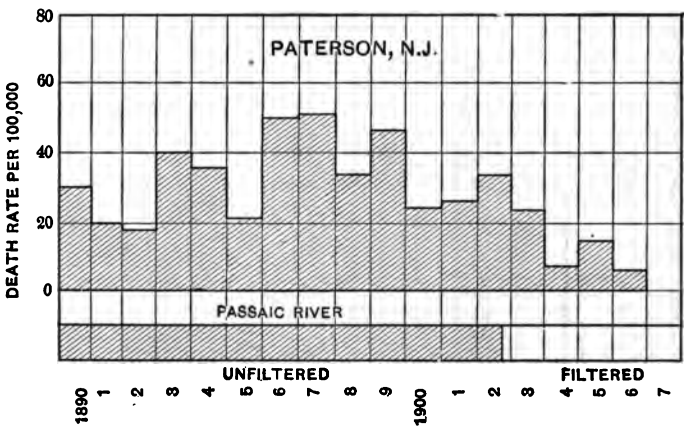


FIG. 36.

Diagram Showing the Relation between the Water-supply and the Typhoid Death-rates of Paterson, N.J.

Paris, France. Filtered water has been recently introduced into one of the suburbs of Paris. Fig. 37 illustrates the improvements in the typhoid fever death-rates that have been produced by it. Until within a comparatively recent period French sanitary engineers have favored ground water rather than filtered water, but recently there has been a changing sentiment and the tendency now is towards the greater use of filtration.

St. Louis, Mo. The water-supply of St. Louis is taken from the Mississippi River, just below where the Missouri enters. The water is intensely muddy at times, and is never clear. Mark Twain or some one else once said that

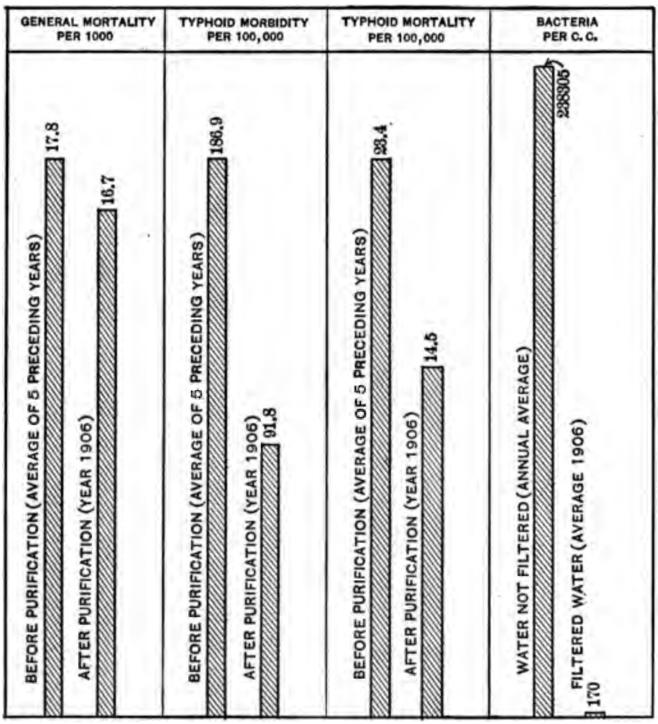


FIG. 37.

Effect of Filtration in Reducing the Typhoid Fever Death-rates and the General Mortality in a Suburb of Paris. (After Chabal.)

when the wind blew over the water it raised a dust. The water is not filtered, but for many years has been passed through settling basins, where 80 or 90 per cent of the mud was removed. In 1904 this process of sedimentation was rendered somewhat more efficient by adding two chemicals to the water before it entered the basins, namely, sulphate of iron (copperas) and lime.

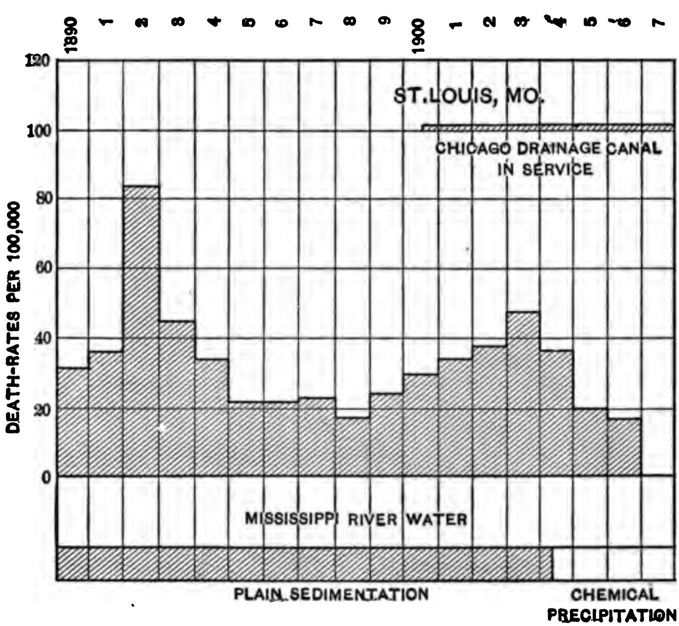


FIG. 38.

Diagram Showing the Relation between the Water-supply and the Typhoid Death-rates in St. Louis, Mo.

Since then the water in the city has been clearer and more healthful, although the quality is still far from that of the effluent of a good filter plant.

The improvement in the water seems to have reduced the typhoid death-rate, which had begun to increase after the opening of the Chicago Drainage Canal.

Philadelphia, Pa. The water-supply of Philadelphia is taken from the Schuylkill and Delaware Rivers.

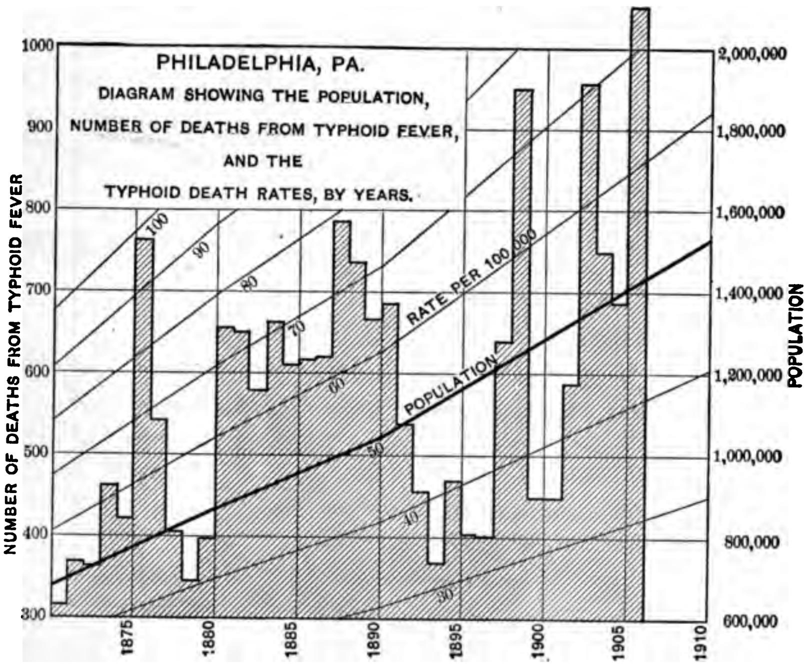


FIG. 39.

There are several different intakes. An extensive filtration system is being installed. Some of the filters are in operation, but many delays have occurred and a large part of the city is still using unfiltered water. Already, the benefits of filtration have been seen in those sections of the city which have filtered water, but the disease has been so prevalent in the other sections of the city supplied with raw water that the death-rates as a whole have not decreased.

Experience as to the Benefit of Filtration. Experience has shown that filtration affords adequate protection. One by one the cities of America are falling into line and taking up this important work. In his paper before the International Engineering Congress in St. Louis, Hazen gave a table showing the progress of filtration, as follows:

TABLE SHOWING THE EXTENT OF FILTRATION IN THE UNITED STATES.

Year.	Total Urban Population in the U. S. (Towns above 2,500).	Population Supplied with Filtered Water.			Percentage of Urban Population Supplied with Filtered Water.
		Sand Filters.	Mechanical Filters.	Total.	
1870	...	None	None	None	0
1880	13,300,000	30,000	...	30,000	0.23
1890	21,400,000	35,000	275,000	310,000	1.45
1900	29,500,000	360,000	1,500,000	1,860,000	6.3
1904	32,700,000	560,000	2,600,000	3,160,000	9.7

Even to-day these figures are out of date, and the proportion of the population supplied with filtered water, or contemplating the early adoption of filtration, is greater than that given. This movement is bound to go on until every city has either a ground water naturally filtered, or a surface water artificially filtered. Clean and wholesome water every self-respecting municipality is bound to have.[1]

Cities where the Introduction of Filters has not been Followed by a Material Reduction in the Typhoid Fever Death-rate.

Youngstown, Ohio. The water-supply at Youngstown is taken from the Mahoning River. While originally of fairly satisfactory quality, its pollution gradually increased and gave rise to a steadily increasing typhoid fever death-rate in the city. In August, 1905, a mechanical filter was introduced. This lowered the rate somewhat, but not as much as was expected. An outbreak occurred during the early part of 1906, which was studied carefully by Mr. Paul Hansen for the Ohio State Board of Health. He found that out of 153 cases contracted in the city, 93 resided in houses where there were no sewers and no public water-supply, while 109 claimed to have used well water only. Many of the houses were in a poor sanitary condition. Investigation showed that this outbreak was not due to the use of the city water, then being filtered, but rather to the use of polluted wells, and to direct contact, including transmission by flies. In 1907 the disease was less prevalent.

Washington, D.C. The city of Washington takes its water-supply from the Potomac River at Great Falls, about 14 miles above the city. For many years it passed through two reservoirs, the Dalecarlia and the George-

[1] Readers interested in the problems of public water-supply should consult Mr. Hazen's recent book on "Clean Water and How to Get it."

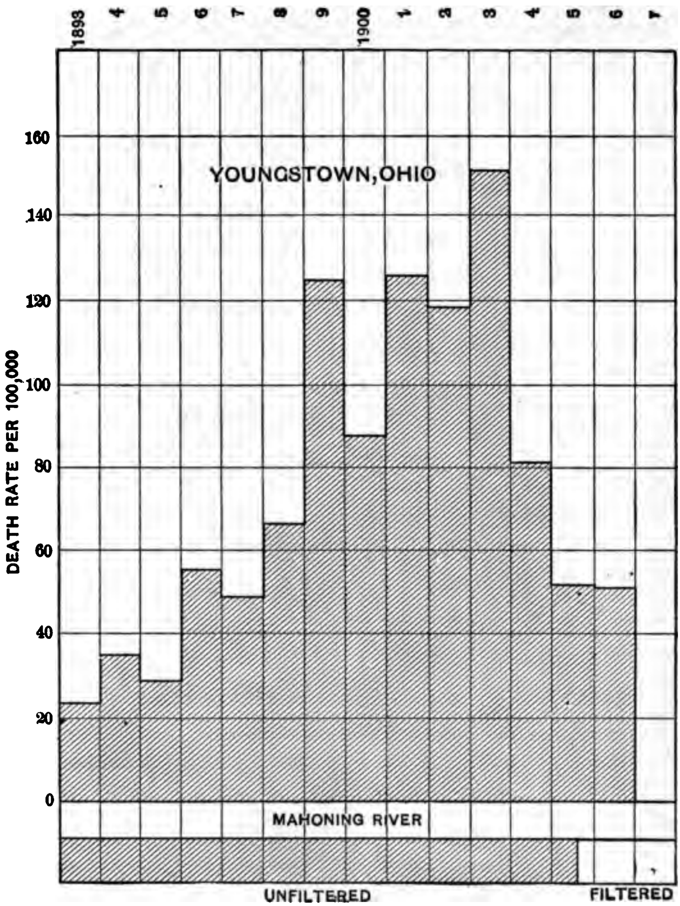


FIG. 40.

Diagram Showing the Relation between the Public Water-supply and the Typhoid Fever Death-rates in Youngstown, Ohio.

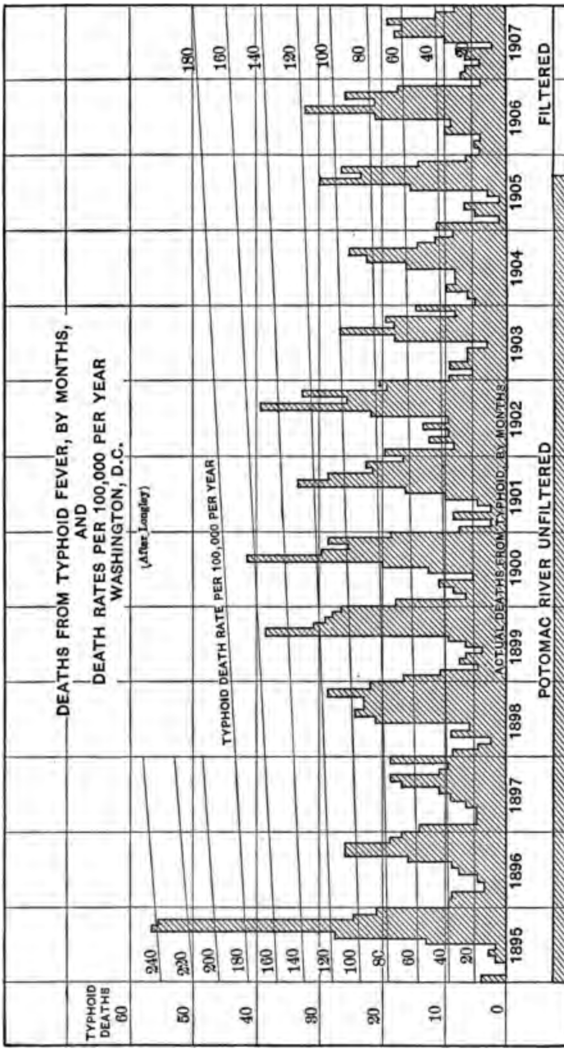

DEATHS FROM TYPHOID FEVER, BY MONTHS,
AND
DEATH RATES PER 100,000 PER YEAR
WASHINGTON, D.C.
(After Longley)
TYPHOID DEATH RATE PER 100,000 PER YEAR
ACTUAL DEATHS FROM TYPHOID, BY MONTHS
TYPHOID DEATHS
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
POTOMAC RIVER UNFILTERED
FILTERED

FIG. 41.

town Reservoir. In 1902 a third reservoir and settling basin, known as the Washington City Reservoir, was put in service. In October, 1905, a filtration plant of the most modern construction was put in operation, so that at the present time the Potomac water passes through three settling basins and a filter before it is delivered to the consumers.

For many years the typhoid fever death-rate in Washington had been high, and it was confidently expected that after the introduction of filtered water the rate would materially decrease. During 1906, however, the death-rate increased slightly instead of decreasing. As it did not seem possible that the filter could be at fault, an extensive investigation of the subject was undertaken by a commission consisting of Dr. M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle. A voluminous report was published in 1907 which in some respects is one of the most instructive reports on the subject of typhoid fever that has appeared in recent years. Although this investigation was most exhaustive, yet the data collected failed to establish the cause of the greater part of the cases which occurred in the city. Indications pointed strongly, however, to milk as being the chief source of the infection, and this was emphasized by Professor Sedgwick, and Mr. Theodore Horton, who also investigated the prevalence of the fever.

Looking back over the history of typhoid fever in Washington the data seem to indicate that not for many years has the water-supply played the major part in the causation of this disease, for it had been already subjected to a partial purification, namely, that due to sedimentation and storage in the three reservoirs. From 1897 up to 1902, when the Washington City Reservoir was built, the typhoid fever rate had been gradually increasing, especially during the winter months, but between 1902 and 1905 there was a falling off in the rate which may be attributed in part, at least, to the greater purification brought about by the increasing use of the additional sedimentation.

If, then, the water had played but little part in the causation of the disease before the filter was constructed, it could not be expected that the operation of the filter would result in any material reduction in the death-rate.

A study of the seasonal distribution of typhoid fever in Washington shows that the disease is chiefly one of summer, and that it has not for many years been prevalent to a considerable extent in the winter and spring. This fact, taken in connection with an abnormally large proportion of cases among children, points to the important influence of milk and direct contagion in the spread of the disease in that city. During the summer of 1907 there was a decrease in the amount of typhoid fever in Washington, due, in part, no doubt to the activities resulting from the investigation referred to.

Cities which have made Slight Changes in the Character of their Water-Supplies.

Boston, Mass. For many years Boston's water-supply was derived from the Sudbury and Cochituate watersheds. These sources, while subject to considerable pollution, had been carefully treated, the sewage of several large communities had been diverted, filter beds had been built to purify the water of certain contami-

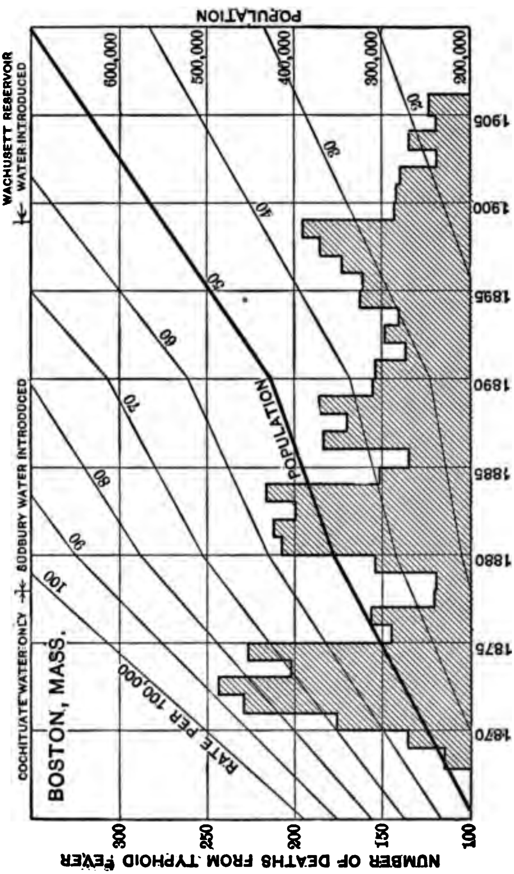


FIG. 42. Diagram Showing the Number of Typhoid Fever Deaths and the Corresponding Death-rates in Boston, Mass.

nated brooks, cesspools and privy nuisances adjacent to the streams had been abated, and a careful patrol maintained. Yet the population was there. It was 776 per square mile on the Sudbury systems, and 282 per square mile in the Cochituate system, so that in spite of the sanitary reforms and the natural benefits of the large storage reservoirs the typhoid fever death-rate in Boston was not as low as it should be.

In 1898 the new supply from the Nashua River, impounded in the great Wachusett Reservoir, was introduced. The Nashua watershed is much less populated than the Sudbury and Cochituate areas, — the number of inhabitants per square mile being only 49. The storage in the reservoir is also longer. Since this new supply has been in use there has been a gradual drop in the typhoid death-rates which may be attributed, in part at least, to the use of better water. As the new supply yields a water less colored and less affected with odors due to algæ, it has been used to the partial exclusion of the old sources.[1] When the consumption increases, however, so that it is necessary to once again draw heavily on the old supplies, and this must happen some time, it will be surprising if the people of Boston remain content to be served with water without filtration. Boston has been for many years a leader in sanitary reforms; it is not likely that she will allow herself to be outstripped by the other large cities in the protection of her water-supply.

New York City. New York City has been for many years supplied with water from the Croton River. At first there was a single reservoir known as the Old Croton

[1] During the last few years the Wachusett Reservoir has furnished about two-thirds of the supply.

Lake. Now there are a dozen or so reservoirs on the various tributary streams, and the Old Croton Lake has

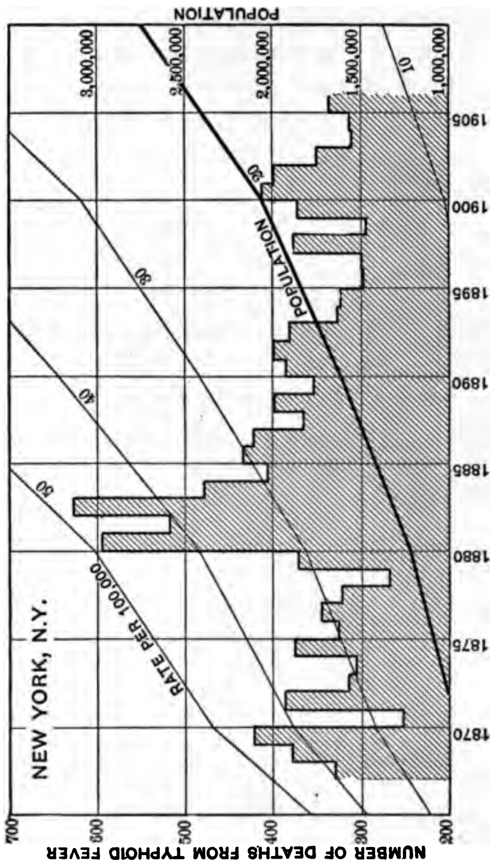


FIG. 43. Diagram Showing the Number of Typhoid Fever Deaths and the Corresponding Death-rates in New York City.

been lost in the new reservoir created by the construction of the great dam. While the general source remains the same throughout, the methods of utilizing the water have been subject to change. A study of the typhoid fever death-rates of the city is interesting in several respects. In 1869–1870 there were severe droughts during which the rate was high. From that time the rate fell gradually to 1879. Then followed some very dry years during which the typhoid fever rate increased materially. Between 1883 and 1897 the rate steadily decreased. This may be attributed to the constantly increasing storage capacity, to the generally more favorable meteorological condition, but especially to the expedients adopted to protect the water-supply from pollution. In 1888 the board of health established rules and regulations relating to the pollution of the watershed, and in 1893 extensive purchases of land and buildings were made along the courses of the streams and around the reservoirs. In 1893 a sewage purification plant was established on the watershed at Brewster. The increase in 1898 was due to the soldiers returning from Cuba after the Spanish War. During the last few years there has been a further slight reduction in the death-rate, which may be due in part to the greater care exercised in preventing contamination from small sources.

It must be remembered, that in a great city like New York, many causes of typhoid fever are in operation, and these are difficult to trace. Nevertheless, the fluctuations in the typhoid fever curve do appear to reflect to some extent the sanitary quality of the public water-supply.

Brooklyn, N.Y. The water-supply of Brooklyn is taken from Long Island, partly from driven wells and

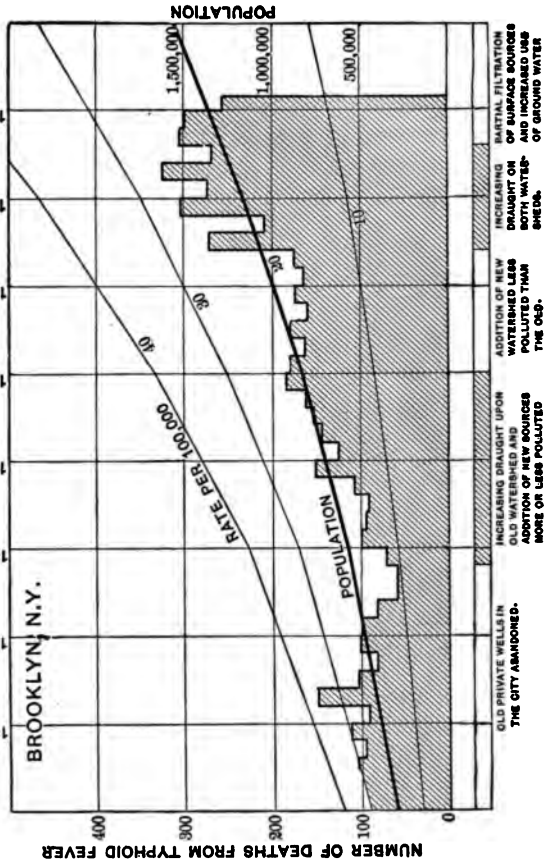


FIG. 44.

Diagram Showing the Number of Typhoid Fever Deaths and the Corresponding Death-rates in Brooklyn, N.Y.

partly from small streams. Twenty years ago the greater part of the water was surface water; to-day the larger portion is ground water.

For a generation the typhoid fever death-rate in

Brooklyn has fluctuated between comparatively narrow limits and has shown much smaller fluctuations than in most of the cities of the country. It has also been comparatively low. Nevertheless a study of the fluctuations in these rates seems to correspond with the changes which have been made in the source of water-supply. Between 1870 and 1880 the death-rate gradually fell, probably because during this time hundreds of polluted wells throughout the city were closed by order of the board of health. Between 1880 and 1890 the rate increased. During this time the draft upon the watershed was constantly increasing, while certain streams somewhat more polluted than those previously in use were added to the supply. From 1890 to 1895 the rate dropped again. Several causes probably contributed to this decrease. The new watershed, first drawn upon in 1891, added a considerable volume of relatively pure water to the supply; in 1892 the Ridgwood Reservoir was enlarged, while during the years 1893-5 arrangements were made for panning the water-closets in the village of Hempstead along one of the important streams. About that time also some of the more polluted sources near the city were cut off.

The increase in 1898 was due to the Spanish War and the further increase in the next few years was due probably to the greater draft upon the watershed. Recently the rate has been falling slightly, and this decrease has been coincident with the establishment of several small filter plants to purify the most threatened surface waters and the addition of new sources of ground water.

Baltimore, Md. The water-supply of Baltimore is impounded surface water used without filtration. The drainage area is about 350 square miles and the population upon it about 32 per square mile. A thorough system of sanitary control is said to be in force. The

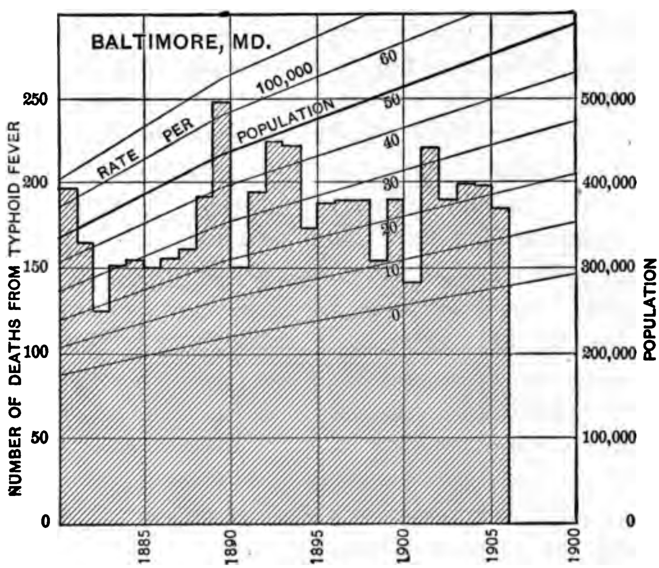


FIG. 45.

Diagram Showing the Number of Deaths from Typhoid Fever and the Corresponding Death-rates for Baltimore, Md.

city has no general sewerage system for house drainage: slops for kitchen, bath-tubs and laundry waste flow in gutters all over the city, and the night soil from thousands of cess pools is carried in scows and teams to truck farms and used on gardens.

Under these circumstances the typhoid fever situation in the city is much better than one might expect.

Cities Supplied with Water Imperfectly Filtered.

If a filter is to give good service and so purify the water that the public will be adequately protected, it must be properly designed and properly operated. A good many illustrations might be mentioned of filters which have failed to do the work expected of them and the recital of these failures has sometimes led unthinking people to believe that all filtration was unsafe. But it must be remembered that there are filters and *filters*. Safety clutches on elevators sometimes fail to work, yet safety clutches are a good thing.

Many of the early mechanical filters were filters only in name; they strained the water, but did not to any great extent remove objects of microscopic size, — consequently they were not able to remove the typhoid bacilli, or to render an infected water safe. Filters of this kind were in use at Augusta and at Bangor, Maine, during the epidemics there.

The first sand filters built in this country were those at Poughkeepsie and Hudson, N.Y. They did good service for many years, but they became outgrown in size, and the pollution of the Hudson River became greater than they could manage, as constructed, so there came a time when as a sanitary safeguard they were not a complete success. When the flood of typhoid fever came down the valley in 1892, both of these cities suffered, but they undoubtedly suffered far less than they would have if no filter at all had been in use. These filters have since been reconstructed and at Poughkeepsie a new sedimentation basin has been recently built.

Like all other structures, filters may deteriorate, parts may wear out, and they may become outgrown. Sometimes these repairs and enlargements are made too late. The filter at Lawrence was outgrown for many years before additions were made. There are many old-type filter plants in the country to-day which ought to be over-hauled, or replaced by modern structures. In building filters it pays to build well. A plant suited to the local conditions will do better work and last longer than the filters of stock pattern, of which so many were put in a few years ago.

Lorain, Ohio. The water-supply of Lorain is taken from Lake Erie at a point where it is considerably polluted by the sewage of the city, which it receives through the Black River. In 1899 a mechanical filter was put in, and for a few years alum was used as the coagulant. Then, in order to reduce expenses, an iron sulphite process was tried. This was found to be unsatisfactory, and during its use the strainer system of the filter was practically destroyed by the action of this chemical. Since 1903, iron sulphate (copperas) and lime have been used.

Before the introduction of the filtered water the typhoid fever death-rates were very high; they fell at once on the introduction of the filter, and remained low for the first few years of its operation. When the filter got out of repair, by reason of the damaging effect of the iron

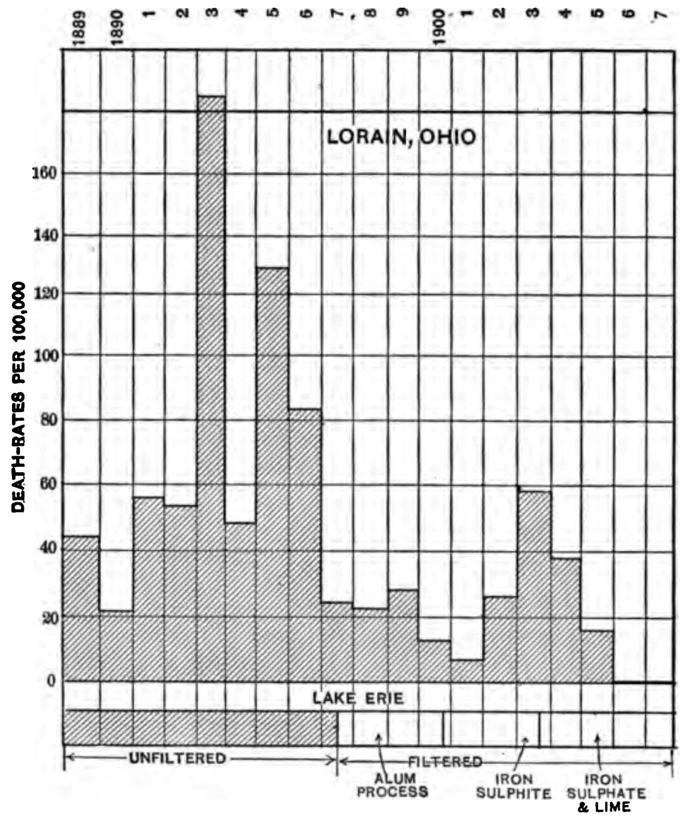


FIG. 46.

Diagram Showing the Relation between the Water-supply and the Typhoid Fever Death-rate in Lorain, Ohio.

sulphite process, the typhoid fever death-rate in the city rose; but recently with somewhat more careful operation the rate has fallen, even though the filter has been much overworked on account of the rapidly increasing population.

These records are interesting as showing the effect of faulty operation of a filter plant on the health of the city. Lorain has recently constructed a new filter.

Stream Pollution and Typhoid Fever.

Typhoid fever often sweeps down a river valley as a sort of wave. A number of instances of this have been already cited. On the Penobscot River the Millinocket epidemic so infected the water that the fever broke out at Oldtown, Brewer and Bangor. On the Kennebec River the Waterville epidemic caused several hundred cases in Augusta and Richmond. On the Merrimac River the disease spread from Lowell to Lawrence and Newburyport.

Perhaps one of the most striking examples of the infection of a river valley is that of the Hudson River and its tributaries. Good water-power sites caused the early development of many large communities along these streams, and naturally these cities and towns emptied their sewage into the rivers as the most convenient places of disposal. Unfortunately, some of the communities lower down used the water for drinking and without filtration. The experience of Albany has been referred to. Typhoid fever raged there until the filter was built. It will be interesting to note the death-rates of some of the other cities along these streams. Fig. 47 shows how the epidemic which occurred in Schenectady in 1890–92 affected the cities down the valley. At that time Albany had no filter plant, and those at

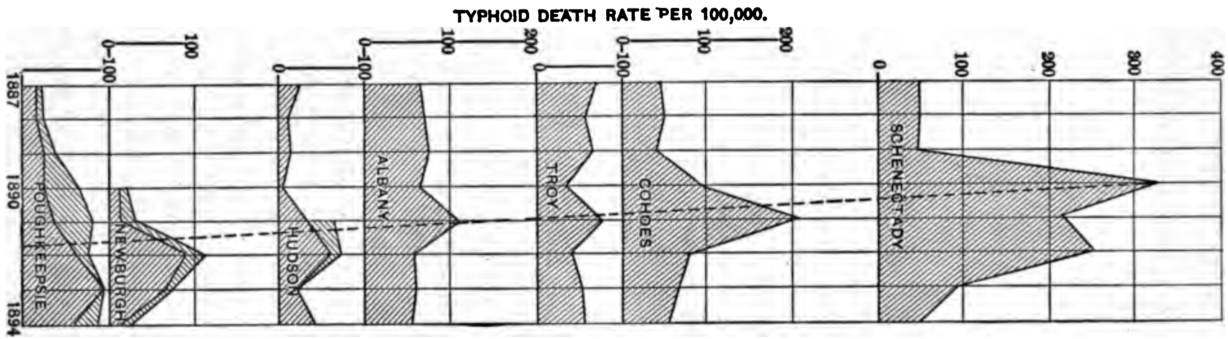


FIG. 47.

Diagram Showing the Relation between the Typhoid Fever Death-rates in Certain Cities along the Mohawk and Hudson Rivers.

Hudson and Poughkeepsie were old and imperfect in operation.

A study of the records of the New York State Department of Health reveals the presence of an exceptional amount of typhoid fever in the Hudson Valley region as compared with other regions. In general the death-rate is about twice as high as that for the entire state. Many other river valleys are likewise overrun with typhoid fever, — the Susquehanna River, the Potomac River, the Ohio River, the Mississippi River, etc.

These waves of typhoid fever which pass down a river valley are, of course, due in the main to the water carriage of the bacilli; but it is conceivable that there may be other modes of transmission, and that the disease may follow the general trend of the lines of travel, just as Asiatic cholera used to follow the oriental caravans and sweep westward from Asia across the continent of Europe.

In seeking to prevent this spread of typhoid fever by rivers, the question has been raised in a number of places as to whether it is better to purify the sewage of an upper city on some river or to filter the water of a lower city. The answer is, — both are desirable and in the course of time both are destined to take place. But, except in a few instances, both are not now needed. It is generally much cheaper to filter the water below than it is to purify the sewage above, and in the present state of the art it is also more efficient. In general, water filtration should come first. Later, when the load is greater than the filters can safely bear, works for the purification of the sewage should be installed, or else double filtration of the water required. What is best to do must depend upon the peculiar circumstances of each case.

The direct pollution of streams by mills and factories, so located that fecal matter from privies and water-closets finds direct access to the water, is a particularly dangerous form of contamination. Several epidemics have arisen from such cases, as for example, in Lowell, Mass., and, probably, Watertown, N.Y.

Stream pollution has another side, however, namely, the nuisances to which the disposal of sewage gives rise, and these, taken in connection with sanitary considerations, are going to result in the establishment of many sewage purification plants along our lakes and streams. Unquestionably many American streams are being rapidly spoiled, and before it is too late much energetic work ought to be done to prevent this. Stream pollution is the result of the prosperity of our cities, but if by increasing our capital in the form of mills and factories, we decrease it in the form of natural water resources, we are not, as a nation, growing rich as rapidly as we think.

The writer is not unaware that in some cases water-supplies have been taken from contaminated sources and used for many years with no apparent serious effect on the public health; and he is not unaware that some engineers, and even some physicians, still hold to the old theory that running water purifies itself to an extent that is sufficient for practical purposes. He has not failed to consider this negative evidence, but in spite of it he holds, as do the majority of sanitary engineers to-day, that water once contaminated is always dangerous until purified.

CHAPTER XI.

THE EFFECT OF MILK-SUPPLIES ON THE TYPHOID FEVER DEATH-RATES OF CITIES.

THIS chapter must be short, as the data for a fair discussion of the subject have not yet been collected. It is one of the problems for the sanitarians of to-day to work out. Up to the present time there are very few, if any, American cities provided with a thoroughly safe and wholesome milk-supply. Pasteurization or sterilization have not become general, although the public conscience is becoming awakened to the need of some such general treatment.

The relative merits of the inspection of the milk farms and the general pasteurization of the milk-supply is being much discussed nowadays. It is argued, on the one hand, that pasteurization is inefficient as ordinarily carried on, that it renders milk less easily digested and that, by destroying certain natural germicidal properties of the milk by heating, it reduces its keeping qualities and renders a subsequent infection more dangerous; and it is argued, on the other hand, that inspection cannot guarantee against infection, that pasteurization can be made efficient, and that the germs of typhoid and the non-sporing bacteria, at least, will not subsequently develop after pasteurization. It is not necessary to recite here all the arguments, scientific and commercial, that have been made, for the subject is one upon which the requisite data have not all been obtained. There are many aspects of the milk question. Typhoid fever is not the only disease involved. Milk may be the means of transmitting scarlet fever, diphtheria, tuberculosis, and other diseases. Dirty milk, even when not directly infected with specific bacteria from some previous case of disease, may produce serious intestinal disorders in bottle-fed infants, — and this may be due simply to a disregard of ordinary cleanliness in the handling of the milk and in the treatment of the milk bottles. It may be too early to prophesy, but in the author's view the solution of the milk question will finally be that in small communities, where there are personal relations between producer and consumer, pasteurization will not be needed, but that in large communities, where there can be no such personal relation, pasteurization or its equivalent will be looked upon as the only safeguard, and will be made compulsory by law. But even with pasteurization required, the inspection of the farms will still be needed. As in the case of water-supplies future sanitarians will demand a clean watershed and then filtration, so in the case of milk-supplies, they will insist upon clean farms and pasteurization.

The advantages of pasteurization are slowly, but surely, being manifested by experience. Some interesting examples are certain cities of England and Scotland.

The diagram (Fig. 48) shows that in Glasgow there has been a marked reduction in typhoid fever during the last three years. This cannot be accounted for by any change in the water-supply, for there has been no change, and the supply is taken from Loch Katrine and

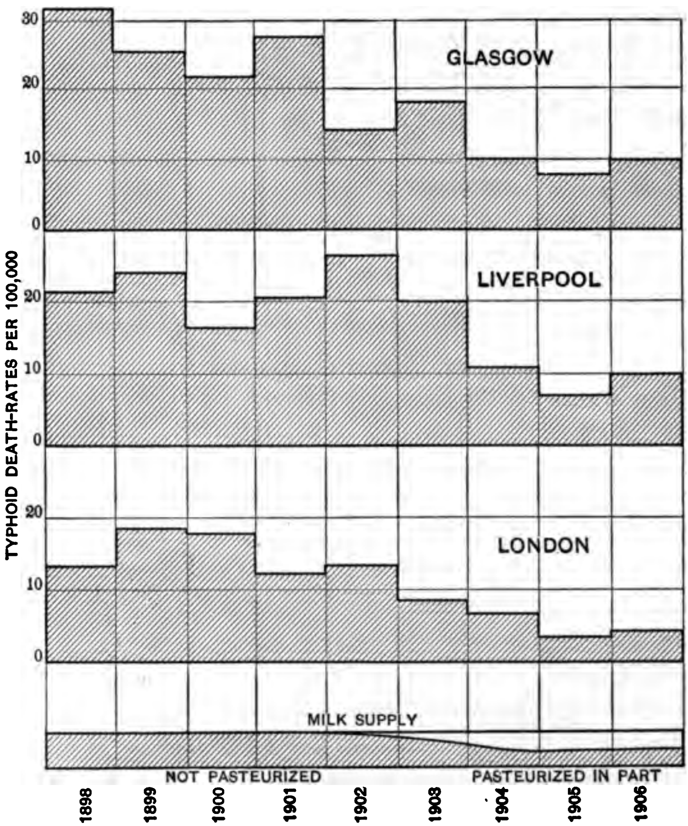


FIG. 48.

is considered to be of excellent quality. About three or four years ago, however, they began a practice of pasteurizing much of the milk sold in the public shops, and this in a great measure is thought to account for the decrease, although it cannot be considered as the only cause.

During the last three or four years there has been a decrease in the amount of enteric fever in Liverpool, although at no time during the last ten years has the rate been excessive. The decrease is probably due in part to improvements which have been made on the water-supply watershed and to greater care regarding the use of oysters, but very largely to the increased use of pasteurized milk. The improvements in the watershed have consisted of the purchase and reforesting of large areas, and the improvement of the sanitary conditions on the farms purchased. The water-supply is filtered. There are now six depots for the sale of sterilized and modified milk. These were established in 1901, and a study of the typhoid statistics of the city shows that the decrease in the death-rate began after 1902. During the last three years the general death-rate among the infants supplied from these depots was about 96 per 1000 as against 171 per 1000 for the entire city.

Another instance of the benefits of pasteurization is that of a certain milkman in Washington, D.C., referred to in the report on the Origin and Prevalence of Typhoid Fever in the District of Columbia in 1906. This dealer sterilized all of his milk bottles and pasteurized all of his milk, and it was noticed that of the large dealers he had the smallest number of typhoid fever cases among his customers in proportion to the milk sold. A comparison of his record with that of the other milk dealers in the city who did not sell pasteurized milk is shown by the following figures:

Dairy.	Gallons of Milk Sold During July, August, September and October, 1906.	Number of Cases of Typhoid Fever During July, August, September and October, 1906.	Number of Cases of Typhoid Fever per 100,000 Gallons of Milk Sold.
A.	35,995	41	113.9
B.	102,867	54	52.5
C.	62,903	23	36.6
D.	51,115	18	35.2
E.	71,350	25	35.0
F.	71,690	17	23.7
G.	31,984	7	22.2
H.	77,098	17	22.0
I.	134,911	29	21.5
J.	27,247	5	18.4
K.	142,986	26	18.2
L.	43,800	8	18.2
M.	119,889	20	16.6
N.	29,247	4	13.7
O.	39,286	5	12.7
P.	**44,496 Pasteurized**	**3**	**6.7**
Q.	31,542[1]	2	6.3

Then there is the general experience of Germany and other countries where the habit of boiling the milk before using is widespread. In such countries the typhoid rates have been proverbially low. In America sanitarians have been inclined to regard death-rates of 15 to 20 per 100,000 as satisfactory for cities having good water-supplies, — but these rates are twice as high as in the milk-boiling countries.

Next in importance to water are the improvements needed in the milk-supplies, — cleaner farms, better

[1] Pasteurization not reported.

methods of distribution, and general pasteurization for all large cities. Progress in this direction thus far has been small, but it is coming, nevertheless, and coming speedily. The additional value of good milk is being recognized by its advance in price. Certified milk commands a premium, and even the price of ordinary milk is increasing. How far these additional charges are justified by increased cost cannot be said, but the additional charges are an indication that the public is demanding a better and a safer quality of milk than it has been getting.

Those interested in the subject of milk should consult the very elaborate report issued by the Marine Hospital Service on "Milk and its Relation to the Public Health."[1] This is an exhaustive treatise, by various authors, on all phases of the milk problem. It contains various data for several hundred epidemics of typhoid fever caused by infected milk.

[1] *Hygienic Laboratory Bulletin*, No. 41.

CHAPTER XII.

THE FINANCIAL ASPECT.

HOWEVER much we may dislike to measure human life in gold dollars, or to balance human suffering against the coin of the realm, we cannot but admit that the financial aspect of typhoid fever is an important matter in the United States, and that it has a very practical bearing on the whole problem. Hence, we are compelled to devote some attention to the *argumentum ad crumenam*.

Having discussed this subject at some length in his book on "The Value of Pure Water," the author takes the liberty of presenting here in an abridged form some of the conclusions there reached.

Financial Value of Human Life. The financial value of a human life is generally taken for purposes of calculation as $5,000, but according to Marshall O. Leighton it varies at different ages from $1,000 to $7,000, as shown by the table on page 274.

It so happens that persons are most exposed to typhoid fever near the age when their life-value is considered greatest.

By combining the life-value at different ages with the age distribution of persons dying of typhoid fever, the resulting average value of persons dying from typhoid fever is found to be $4,634, which is very close to the figure ordinarily used.

Age.	Estimated Value of Human Life.	Per cent of Deaths from Typhoid Fever.	Product of Columns 2 and 3.
0– 5 years	$1,500	5.0	$7,510
5–10 "	2,300	5.9	13,570
10–15 "	2,500	7.2	18,000
15–20 "	3,000	13.1	39,300
20–25 "	5,000	16.7	83,500
25–30 "	7,500	13.2	99,100
30–35 "	7,000	9.9	69,300
35–40 "	6,000	8.0	48,000
40–45 "	5,500	5.6	30,900
45–50 "	5,000	4.0	20,000
50–55 "	4,500	3.3	15,000
55–60 "	4,500	2.6	11,700
60–65 "	2,000	2.1	4,200
65–70 "	1,000	1.5	1,500
70– "	1,000	1.9	1,900
Total		100.00	$463,480

Average value of life of persons dying from typhoid fever, $4,634.

The percentage fatality of typhoid fever patients is sometimes stated as 10 per cent, that is, ten cases for every death; but it has been shown elsewhere that 12 to 15 cases for each death would be nearer the truth. The expense of medical treatment, nursing, and medicine, the loss of wages for a month or more, together with other attending expenses and inconveniences, would doubtless aggregate at least $100 per case, or $1,000 for the 10 cases corresponding to one death. If the estimate of $100 is considered too large, it may be answered that any excess is more than offset by the fact that there are more often from 12 to 15 cases for each death than there are 10. It may be fairly assumed, therefore, that $6,000 is a very moderate estimate of the financial loss to a community from typhoid fever for each death from that disease.

What Typhoid Fever Costs the Country. The United States Census of 1900 stated that during that year there were 35,379 reported deaths from typhoid fever in the United States. If it be assumed that each one of these represents a loss of capital to the community of $6,000, the total amount is found to be $212,000,000. Of the 35,379 deaths from this disease, probably three-quarters of them at least could have been prevented; that is, the needless loss of vital capital was about $150,000,000. This was for only one year, and the same thing is continually going on, although, thanks to sanitary science, to a lessening extent.

Such figures as these are often set forth with some variations to show the effect of typhoid fever. They have but little definite value, but, taken in connection with the effects and cost of water filtration and other sanitary measures, they serve to show the enormous saving that it is possible to bring about.

To filter all the water-supplies of the important cities of the country, and to institute such sanitary reforms that three-quarters of the deaths from typhoid fever would be prevented, would cost only a small part of the loss from this disease. As an illustration of what can be done, let us consider the effects of water filtration.

EFFECT OF FILTRATION ON DEATH-RATES AT ALBANY, N.Y., AND A COMPARISON WITH TROY, N.Y., WHERE THE WATER WAS NOT FILTERED.

ALBANY.

	Death-Rates per 100,000.			
	1894–98, Before Filtration at Albany.	1900–04, After Filtration at Albany.	Difference.	Per Cent Reduction of Death-Rates.
Typhoid fever	104	26	78	75
Diarrheal diseases	125	53	72	57
Children under 5 years	606	309	297	49
Total deaths	2,264	1,868	378	17

TROY.

Typhoid fever	57	57	0	0
Diarrheal diseases	116	102	14	12
Children under 5 years	531	435	96	18
Total deaths	2,157	2,028	129	6

Filtered water was introduced into Albany in 1899. The water-supply of Troy has remained practically unchanged.

Effect of Filtration. Typhoid fever is by no means the only disease transmitted by contaminated water. Dysentery and various other diarrheal diseases precede it or follow in its train, and in most instances these are probably due to the same general sources of contamination as those which caused the typhoid fever, although, of course, to different specific infections. The reduction of the typhoid fever death-rate following the substitution of a pure water for a contaminated water is often accompanied by a drop in the death-rate from other diseases. Thus, if the five years before and after filtered water was introduced into Albany, N.Y., are compared, it will be seen that the reductions in deaths from general diarrheal diseases and the deaths of children under five years of age were much greater than in the case of typhoid fever. There was also a reduction in malaria, but this probably represents faulty diagnosis of typhoid fever cases before the introduction of the filters, rather than a real reduction of malaria. That the reduction of infant mortality and deaths from diarrheal diseases was not due to other conditions seems probable from the fact that in the neighboring city of Troy, where the water-supply was not changed, there was no such diminution during the same period.

Hazen, in his paper on "Purification of Water in America," read at the International Engineering Congress at St. Louis, called attention to this same fact, that after the change from an impure to a pure supply of water, the general death-rate of certain communities investigated fell by an amount considerably greater than that resulting from typhoid fever alone — indicating either that certain other infectious diseases were reduced more than typhoid fever, or that the general health tone of the community had been improved. Thus, for five cities where the water-supply had been radically improved he found:

	Per 100,000
Reduction in total death-rate in five cities with the introduction of a pure water-supply	440
Normal reduction due to general improved sanitary conditions, computed from average of cities similarly situated, but with no radical change in water-supply	137
Difference, being decrease in death-rate attributable to change in water-supply	303
Of this, the reduction in deaths from typhoid fever was	71
Leaving deaths from other causes attributable to change in water-supply	232

From these facts it is evident that to place the financial loss to a community as $6,000 for each death from typhoid fever due to the public water-supply is to use too low a figure. It probably ought to be several times as high; but recognizing the lower financial value placed on the lives of infants, and the less serious character of the other diseases, and wishing to be as conservative as possible, for the reason that typhoid fever is not entirely a water-borne disease, $10,000 per typhoid death has been used in the calculation which follows.

Since typhoid fever is a disease which may be transmitted in other way than by water it is necessary to allow a certain death-rate for these other causes, for even in a city where the water-supply is perfect there may still be some typhoid fever. To establish a figure, this typhoid fever of miscellaneous origin is a difficult matter, but for purposes of calculation we may assume it to be determined and represent it by the letter N. It is used as a synonym for the "residual" typhoid already referred to, and is, of course, variable and subject to local conditions.

If we assume that all typhoid fever in excess of N is due to the water-supply, and if we assume that the daily consumption of water is 100 gallons per capita, then letting T equal the typhoid fever death-rate per 100,000 —

$(T - N)$ 10,000 = loss to the community in dollars for $365 \times 100 \times 100,000$ gallons of water, or $D = \frac{(T - N)\ 1,000}{365} = 2.75\ (T - N)$, where D stands for the loss in dollars per million gallons of water used.

Suppose the average typhoid fever death-rate for a community which has a somewhat polluted water-supply has averaged 43 per 100,000 for a period of five years, and suppose that for this place the value of N is estimated as 15, then —

$D = 2.75\ (43 - 15) = \$76.72$ if the per capita consumption is 100 gallons. If the consumption per capita is 115 gallons, D would be $\frac{100}{115}$ of \$76.72, or \$66.71; if it were 63 gallons per capita, then D would equal $\frac{100}{63}$ of \$76.72, or \$121.77.

The following examples illustrate to what extent the sanitary value of a polluted public water-supply is increased by an efficient system of filtration:

Lawrence, Mass. —

Water-supply, Merrimac River, filtered by a slow sand filter.
Population, 70,000.
Water consumption, 40 gallons per capita daily.
Before filtration the typhoid fever death-rate was 121 per 100,000; since then it has been 26.
Before filtration $D = 2.75\ (121 - 20) \times \frac{100}{40} = \$693$.
After filtration $D = 2.75\ (26 - 20) \times \frac{100}{40} = \$41$.
Increase in sanitary value = \$693 − \$41 = \$652 per million gallons, or \$665,000 per year, or \$9.50 per year per capita.

Albany, N.Y. —

Water-supply, Hudson River, filtered by sand filter.
Population, 95,000.
Water consumption, 165 gallons per capita daily.
Before filtration the typhoid fever death-rate was 104 per 100,000; since then it has been 26.
Before filtration $D = 2.75\,(104 - 20) \times \frac{100}{165} = \$140$.
After filtration $D = 2.75\,(26 - 20) \times \frac{100}{165} = \$10$.
Increase in sanitary value $= \$140 - \$10 = \$130$ per million gallons, or $450,000 per year, or $4.75 per capita per year.

Binghamton, N.Y. —

Water-supply, Susquehanna River, filtered by a mechanical filter.
Population, 42,000 (approximately).
Water consumption, 160 gallons per capita daily.
Typhoid fever death-rate before filtration, 49; after filtration, 11 per 100,000.
Before filtration $D = 2.75\,(49 - 11) \times \frac{100}{160} = \$65$.
After filtration $D = 2.75\,(11 - 11) \times \frac{100}{160} = 0$.
Increase in sanitary value = $65.00 per million gallons, or $160,000 per year, or $3.80 per capita per year.

Watertown, N.Y. —

Water-supply, Black River filtered by Mechanical filter.
Population, 25,500 (approximately).
Water consumption, 160 gallons per capita daily.
Typhoid fever death-rate before filtration, 68 per 100,000; after filtration, 19.5.
Before filtration $D = 2.75\,(68 - 20) \times \frac{100}{160} = \$82.50$.
After filtration $D = 2.75\,(20 - 20) \times \frac{100}{10} = 0$.
Increase in sanitary value $82.50 per million gallons, or $120,000 per year, or $4.75 per capita per year.

Illustrations like the above might be multiplied, but the four cases selected are sufficient to illustrate the general fact. It is easily seen from them that the filtration of a polluted public water-supply increases to a very great extent the vital assets of a community, and the increase in most cases is many times greater than the cost of constructing and operating the works. Money paid to the doctor, the apothecary, and the undertaker is not, in one sense, a loss to a community, as it is merely a transference of money from one man's pocket to another's, but in the broader sense any loss of productive capacity or any unnecessary expenditure is a loss. Deaths from typhoid fever and from other diseases, however, represent a very material loss of the productive capacity of a community, and consequently a decrease in what may be termed the "vital assets." In the case of the city of Albany, for instance, the increased worth of the water to the city, because of its efficient filtration, amounts to \$475,000 per year, of which at least \$350,000 may be considered as a real increase in the vital assets of the city.

If in the formula $D = \$2.75\ (T - N)$ we let $T - N = 1$, then $D = \$2.75$; that is, a decrease in the typhoid fever death-rate of 1 per 100,000 causes an increase in the vital assets of the city of \$2.75 for each million gallons of the public water-supply (assuming this to be 100 gallons per capita), or \$0.10 per capita per year for each unit reduction of the typhoid fever death-rate per 100,000. In other words the decrease in the typhoid death-rate per 100,000 divided by 10 gives the increased vital assets of the community in dollars per capita per year. Thus in the case of Albany, above given, the reduction in the typhoid fever death-rate was 78 per 100,000. On the basis of 10 cents per capita per unit decrease, this would amount to $\$0.10 \times 78 \times 95,000 = \$741,000$ per year, assuming a per capita consumption of 100 gallons daily, or \$450,000 for a per capita consumption of 165 gallons daily, which is the figure stated above.

Looking at the matter in another way, it may be said that the purification of a polluted water is a sort of life insurance for the people, the value of which is equal to 10 cents per capita for each unit decrease in the typhoid fever death-rate per 100,000 which it brings about. Such a sum capitalized represents a large amount of money. In Albany, for example, where the typhoid fever death-rate has been reduced 78 per 100,000, the annual saving of life-value would be $7.80 per capita. Capitalized on the basis of an annual life-insurance premium of $17 per thousand, this would represent an insurance policy of about $460 per year for each inhabitant, or $2,300 for each head of a family.

Effect of Contamination. The average death-rate from typhoid fever in American cities which have more than 30,000 inhabitants is about 35 per 100,000. Applying formula (1), and assuming a value of 20 for N, then

$$D = 2.75\ (35 - 20) = \$41.25;$$

that is, the average depreciation value of the water-supplies of our American cities, taken as a whole, is $41.25 per million gallons, because of their unsanitary quality, or about $15,000 per annum for each million gallons a day of supply.

The above figure takes into account both good and bad supplies. The average typhoid fever death-rate in those cities which have reasonably good water-supplies may be taken in round numbers as about 20, while in those cities which have supplies more or less contaminated it varies from this up to 40 or 60. In some of the worst cases it is more than 100 per 100,000. In Pittsburg, for example, the typhoid death-rate for several years has averaged 120.

Here, according to formula (1), $D = 2.75\ (120 - 20) =$ \$275 per million gallons. This is figured, however, on a per capita water consumption of 100 gallons a day. The actual consumption is about 250 gallons per capita per day; hence D should be taken as $\frac{100}{250}$ of \$275, or \$110 per million gallons. Each million gallons of polluted Allegheny River water pumped to Pittsburg has, therefore, reduced the vital assets of the community by \$110. This, for a population of 350,000, amounts to \$3,850,000 per year—a sum enormously greater than the cost of making the water pure.

Classifying water supplies according to their source, the following will give a general idea as to the amount of depreciation of various types of water from the sanitary standpoint, based on general average typhoid fever death-rates:

CHARACTER OF WATER SUPPLY.

	Amount of Depreciation in Dollars per Million Gallons.
1. Ground waters, except in cases where pollution is excessive, or where wells are driven in rock or soil abounding in fissures	\$0.00
2. Filtered waters (assuming modern methods of construction and operation)	0.00
3. Surface waters —	
(a) Ordinary upland waters, with insignificant contamination	\$0.00 to 15.00
(b) Slightly contaminated waters, with good storage in lakes or large reservoirs	10.00 to 50.00
(c) River waters, slightly contaminated, little or no storage	25.00 to 100.00
(d) River waters, much contaminated, little or no storage	50.00 to 200.00

Conclusion. When the appalling ravages of typhoid fever and the accompanying great financial losses are considered, the sums spent in preventing the disease appear beggarly. This is true all along the line from the government of the nation to that of the smallest village.

We have no national department of health. We ought to have such a department, thoroughly organized and endowed with interstate authority. And the annual preventable losses from typhoid fever alone would more than support such a department.

Our army medical corps is entirely inadequate to the service, and organized upon a wrong principle. The losses from typhoid fever in the Spanish War would have paid for an adequate service ten times over.

Some of our states have no health departments worthy of the name, and in some there is not even an attempt made to collect the vital statistics. Even in New York state, the wealthiest state in the union, the appropriations for the department of health are ridiculously meager, and the work of the department is correspondingly insufficient for the needs of the community.

Some states, on the other hand, have too many sanitary authorities, and water-supply commissions and sewerage commissions eat up appropriations and bring about unhappy conditions of divided authority. The states provided with a strong central board of health, well organized and supported are the states in which sanitary reforms have made greatest progress.

Many cities of the country have no boards of health or health officers, or, if they have, these officers are such only in name, serving without pay, and knowing little about the principles of sanitary science.

To remedy all these conditions will cost money, but it will pay. It will pay not only in the satisfaction of having clean and healthful cities to live in, not only in the joy of having relieved the suffering and saved the dying, but it will pay in hard cash.

Although this country has a long road to travel before reaching the goal of perfect sanitation, yet during the last decade it has traveled a long way on that road. The nation should be proud of the state of Massachusetts for her pioneer work in sanitary science; it should be proud of such an example as the city of Montclair, N.J., jealously guarding the health of her citizens; it should be proud of the work done by many civic organizations, many an editor in his chair, many a lawyer struggling for better sanitary laws, many a family physician doing self-sacrificing work that humanity never dreams of, and many an engineer working out on a large scale what the laboratory student has learned from his test tubes and his microscope. And the United States should be proud of her citizens who, in ever increasing numbers and in many states, are taking an intelligent interest in the care of their own premises, in the sanitation of their city, and in the universally important subjects of health and cleanliness.

APPENDIX I.

THE USE OF DISINFECTANTS.

Definitions. There are three common terms that are sometimes used interchangeably, but to do so is incorrect and tends to a confusion of ideas. These terms are disinfectants, antiseptics and deodorizers.

Deodorizers are substances that destroy or cover up odors, without necessarily killing germs or preventing their growth. Antiseptic substances prevent the development of bacteria, without necessarily killing them and their spores. Disinfectants actually kill the germs. Disinfectants and antiseptics differ in degree rather than in kind. Formaldehyde used in minute quantities may act as an antiseptic agent; used in larger quantities it may act as a disinfectant.

Disinfectants and antiseptics may tend to reduce odors by arresting or preventing decomposition, but this is not their principal function.

Deodorizers have their legitimate uses, but they are of little use in typhoid fever. When there is danger from disease germs, disinfectants only are adequate to the task. The chief objection to the use of deodorizers as a class is that they tend to give a false sense of security.

Methods of Disinfection. The methods of disinfection may be divided into four groups:

1. Burning with fire.
2. Killing with dry heat.
3. Killing with hot water and steam.
4. Poisoning with chemicals.

These will be discussed only in so far as they relate to typhoid fever. As the typhoid bacillus does not form spores its destruction is less difficult than it otherwise would be, and as the germ is not thrown off into the air to any great extent the problem is simpler than in the case of diphtheria, scarlet fever, smallpox and such diseases.

Fire. It goes almost without saying that the burning of infected articles destroys all germ life, and this is the safest and best way of destroying many things used around a typhoid patient, if they have little value. Old bedding, old handkerchiefs and cloths used as substitutes for handkerchiefs should be burned in the stove. Toilet paper may be conveniently disposed of in the same way. Sometimes the stools themselves are mixed with sawdust and burned.

Dry Heat. Articles exposed to dry heat (temperatures of 150° C. or more) in an oven or "hot-air sterilizer" for an hour will have any typhoid germs that they may contain completely destroyed, so far as they lie upon the surface of the articles. Dry heat does not penetrate to the interior of packages or articles piled together as moist heat does. It is only to be used for articles that might be destroyed by moist heat.

Steam. Steam under a slight pressure is useful in hospital work, but is almost never available elsewhere. A few minutes' exposure to steam which has a pressure of 15 pounds or more per square inch is sufficient to kill typhoid bacilli. Steam at atmospheric pressure, that is, the steam arising from boiling water in an open dish, has practically the same effect as boiling water.

Boiling. Typhoid bacilli are killed in boiling water or in streaming steam in a very few minutes, but if the water is not up to the boiling point a somewhat longer time is required. If a steam sterilizer, such as an "Arnold," is used, an exposure of 30 minutes is sufficient to insure safety, but if articles are put into boiling water it is better to let them remain there an hour or even two hours.

Boiling is a convenient way to sterilize the knives, forks, spoons and plates used by the patient, and also bed linen, underwear, handkerchiefs, etc., although in the case of these fabrics chemical disinfectants should first be used.

Chemical Disinfectants. The most useful chemical disinfectants in typhoid fever cases are:

1. Ordinary quicklime, or lime freshly slaked.
2. Chloride of lime. (Bleaching powder.)
3. Carbolic acid.
4. Corrosive sublimate, or bichloride of mercury.

These chemicals are all poisons and are listed in the order of their poisonous effect. The last-named chemical is exceedingly poisonous and has to be used very carefully, and all the more so because it has no odor to serve as a warning as in the case of carbolic acid and chloride of lime.

It should be remembered also that corrosive sublimate acts on some metals. Solutions of it should not be kept in metal vessels, but in wooden pails, or tubs or earthern or glass jars. It should not be used for disinfecting silverware, and one should be careful not to wash the hands in it without first removing finger rings. Solutions of chloride of lime, carbolic acid and corrosive sublimate may injure the lead pipes of plumbing fixtures if used in large quantities without flushing. In case these solutions are put into a water-closet, let the water run freely.

The relative value of these disinfecting substances varies with the uses to which they are put. Generally speaking, carbolic acid and corrosive sublimate are best to use around the body of the patient and in the sick room; while chloride of lime and quicklime are most serviceable for disinfecting water-closets, fecal matter in chamber vessels, and cesspools, and for general out-of-doors work. Lime is especially valuable in country practice, while the other disinfectants are more convenient for use in city apartments, hospitals, etc.

Use of Lime. Lime is comparatively cheap, costing from less than half a cent to a cent a pound, according to locality and quantity purchased. Old lime, which has become "air-slaked" is of no use whatever. Lime freshly burnt is known as "quicklime." It comes in irregular lumps which are easily broken. The dry substances may be used for disinfecting fecal matter. In chamber vessels use about as much as the volume of the substance to be disinfected. In water-closets sprinkle freely about the seat and floor in front of the seat, and after each evacuation cover the feces with the powdered lime until white. In cesspools use about 3 to 5 pounds for each cubic foot of contents. This might amount to a barrel of lime for the ordinary sized cesspool of a one-family house.

Often it is more convenient to use "milk of lime." This may be easily made by slacking the lime, that is, by mixing it carefully with something less than its own weight of water, and then adding to the hydrated lime thus made about eight or ten times its weight of water. The product is a sort of white-wash, which can be used for all of the disinfecting purposes above mentioned. It ought to be freshly prepared, but will keep a few days in a closed jar with the air excluded.

Use of Chloride of Lime. Chloride of lime is also comparatively inexpensive. It can be purchased in retail lots for 3 or 4 cents a pound, and in quantities for much less. It is sold as a dry powder in sealed packages. Chemically, chloride of lime is a hypochlorite of calcium. It owes its disinfecting qualities to the "available chlorine." Some grades contain more of this than others, and are therefore worth more. Common grades contain 20 to 30 per cent of available chlorine, but some grades prepared by recently introduced electrolytic processes contain as high as 35 or 40 per cent of available chlorine.

Chloride of lime may be used dry in place of ordinary quicklime, and less may be used, but quicklime is cheaper, less odorous, and on the whole better, provided enough of it is used.

To prepare a disinfecting solution of chloride of lime, dissolve a third of a pound (something less than a cupful) of the dry substance in a gallon of water.

Use about one quart of such a solution to disinfect each fecal discharge; and for disinfecting urine, add volume for volume. Allow these to stand for at least two hours in order to give time for thorough disinfection. Break up any lumps of fecal matter with a stick, and immediately burn the stick; or if a glass rod is used, sterilize the rod.

Prepare the solution of chloride of lime each time when required, or at least once each day.

Use of Carbolic Acid. The best grade of carbolic acid is purchased as a solid, but it may be made liquid by adding a small quantity of water and letting the bottle stand in boiling water. Crude carbolic acid is sold as a liquid. The purer forms are not needed for disinfecting purposes. A satisfactory quality of carbolic acid can be purchased for 25 to 75 cents per gallon.

A 5 per cent solution of carbolic acid is that generally used, that is, about twenty times as much water as acid, — or say half a cupful of carbolic acid to a gallon of water. Such a solution may be used for soaking bed linen, underwear, handkerchiefs, towels, napkins, etc., before boiling. Such fabrics should soak in the disinfecting solution for upwards of an hour. Such a solution may be also used instead of chloride of lime for disinfecting fecal discharges and urine.

For disinfecting the hands or for bathing the patient, a 5 per cent solution of carbolic acid is too strong. A 2 per cent solution, or one something less than half as strong, is preferable, and, as the acid is rather harsh to the skin, an equal volume of glycerine should be added to each quart of solution.

It is not so important to have these solutions freshly prepared as in the case of chloride of lime.

Use of Corrosive Sublimate. Corrosive sublimate is purchased as a white crystalline solid. It costs at retail from 75 cents to a dollar per pound. It should not be used without dissolving in water. Solutions of different strengths are used for different purposes, as follows:

Strong Solution. (1:500.) Used for disinfecting fecal matter, urine, etc.

Corrosive sublimate, one ounce (about a tablespoonful).

Hydrochloric acid (muriatic acid), one-half ounce (about two tablespoonfuls).

Water, one gallon.

Permanganate of potash (10 grains) may be added to give a color to the solution, in order that it may not be mistaken for water. Common washing blueing is equally useful for this purpose.

Medium Solution. (1:1000.) Used for disinfecting clothing, bed linen, etc., and often used for fecal matter. Also used for disinfecting the hands, for disinfecting clinical thermometers, syringes, glassware, woodwork, door-knobs, etc. It is prepared by adding one teaspoonful of the chemical to one gallon of water. In this solution no hydrochloric acid need be added, but sometimes a quantity of ammonium chloride, equal in weight to the corrosive sublimate, is used.

Weak Solutions. Weaker solutions are used for disinfecting the body of the patient, as follows:

(1:3000.) For bathing the patient after each stool, for washing the scalp, and for general bathing.

(1:8000.) May be used as a nasal spray, but for cleansing the mouth, lips and nose, solutions of boracic acid are to be preferred.

In using corrosive sublimate it should be remembered that the solutions are poisonous. Especial care should be taken with strong solutions if one has cuts on the hands.

Corrosive sublimate is somewhat slower in action than chloride of lime. At least two hours' contact should be allowed.

Use of Other Chemicals. Certain other chemicals may be used for disinfecting purposes in place of those mentioned, but they are not as satisfactory for typhoid fever. Among these may be mentioned:

Formaldehyde solutions, 1:20.

Copper sulphate (Blue vitriol), 10 per cent solution.

Iron sulphate (Copperas).

Zinc chloride, 10 per cent solution.

Besides these there are many other substances, such as lysol, that are useful in the sick room and about the patient.

Use of Urotropin. Urotropin is a valuable urinary disinfectant. It should be used only on prescription by a physician. The usual dose is 5 to 7 grains three times a day, preferably after meals, continued for two or three days, or until an examination of the urine shows that typhoid bacilli are absent. The tablets should be dissolved in a tumblerful of water (temperature less than 80° F.).

Fumigation. Fumigation, as practised in the case of scarlet fever, measles, etc., is not generally considered necessary in typhoid fever. Nevertheless on account of its contagiousness, fumigation is a wise precaution, especially in those instances where pulmonary complications supervene. In any case, however, woodwork, doorknobs, etc., should be washed with disinfectants and the bedding, mattresses, etc., thoroughly cleansed.

APPENDIX II.

HOUSE FLIES.

(Chiefly from a paper by Dr. L. O. Howard, Chief of the Bureau of Entomology, United States Department of Agriculture, Circular No. 71.)

Common Species. There are several species of flies which are commonly found in houses, although but one of these should properly be called the house fly. This is the *Musca domestica* (Fig. 49 *a*) and is a medium-sized, grayish fly, with its mouth parts spread out at the tip for sucking up liquid substances. It breeds in manure and dooryard filth and is found in nearly all parts of the world. On account of the conformation of its mouth parts, the house fly cannot bite, yet no impression is stronger in the minds of most people than that this insect does occasionally bite. This impression is due to the frequent occurrence in houses of another fly (*Stomoxys calcitrans*), which is called the stable fly, and which, while closely resembling the house fly, differs from it in the important particular that its mouth parts are formed for piercing the skin. It is perhaps second in point of abundance to the house fly in most portions of the Northeastern States.

A third species, commonly called the cluster fly (*Pollenia rudis*), is a very frequent visitant of houses, particularly in the spring and fall. This fly is somewhat larger than the house fly, with a dark-colored, smooth abdomen and a sprinkling of yellowish hairs. It is not so active as the house fly, and particularly, in the fall, is very sluggish.

A fourth species is another stable fly, known as *Muscina stabulans*, a form which almost exactly resembles

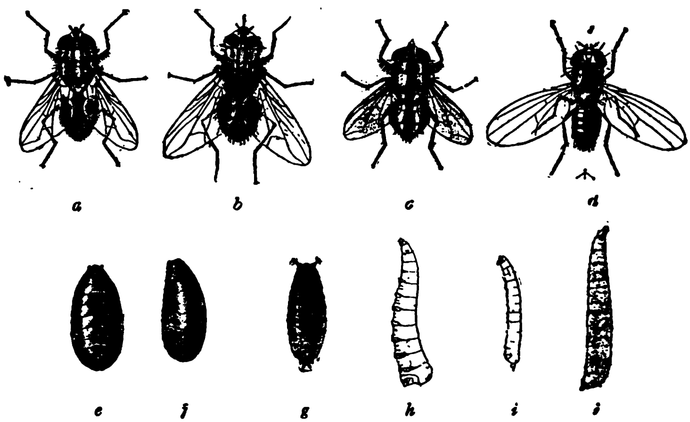


FIG. 49.

Some Common Species of Flies and their Larvæ and Puparia.
(After L. O. Howard.)

a. Musca domestica, the common house fly.
b. Stomoxys calcitrans, the stable fly.
c. Phormia terrænovæ, the small blue bottle fly.
d. Drosophila ampelophia; the small fruit fly.
e, f, g. Puparia.
h, i, j. Larvæ.

the house fly in general appearance, and which does not bite as does the biting stable fly. It breeds in decaying vegetable matter and in excrement.

Several species of metallic, greenish or bluish flies are also occasionally found in houses, the most abundant of which is the so-called blue-bottle fly (*Calliphora ery-*

throcephala). This insect is also called the blow-fly or meat-fly and breeds in decaying animal material. A smaller species, which may be called the small blue-bottle fly, is *Phormia terrænovæ;* and a third, which is green in color and about the size of the large blue-bottle, is *Lucilia cæsar*.

There is still another species, smaller than any of those so far mentioned, which is known to entomologists as *Homalomyia canicularis*, sometimes called the small house fly. *H. canicularis* is distinguished from the ordinary house fly by its paler and more pointed body and conical shape. The male, which is much commoner than the female, has large pale patches at the base of the abdomen, which are translucent when the fly is seen on a window pane.

Still another fly, and this one is still smaller, is a jet-black species known as the window fly (*Scenopinus fenestralis*). It breeds in the dust under carpets, and its larva is a white, very slender, almost thread-like creature.

In the autumn, when fruit appears on the sideboard, many specimens of a small fruit fly (*Drosophila ampelophila*) make their appearance, attracted by the odor of overripe fruit.

A small, slender fly, not infrequently seen in houses, especially upon window panes, is *Sepsis violacea*.

All of these species, however, are greatly dwarfed in numbers by the common house fly. In 1900 collections were made of the flies in dining rooms in different parts of the country, and out of a total of 23,087 flies, 22,808 were *Musca domestica*, that is, 98.8 per cent of the whole number captured. The remainder, consisting of 1.2 per cent of the whole, comprised various species, including those mentioned above.

Life History of Flies. *Musca domestica* commonly lays its eggs upon horse-manure. This substance seems to be its favorite larval food. It will deposit its eggs on cow manure and will also breed in human excrement, and from this habit it becomes very dangerous to the health of human beings, carrying, as it does, the germs of intestinal diseases such as typhoid fever and cholera from excreta to food supplies. It will also lay its eggs upon other decaying vegetable and animal material, but of the flies that infest dwelling houses, both in cities and on farms, a vast proportion comes from horse manure. In hot weather each female fly lays about 120 eggs, which hatch in eight hours, the larva period lasting five days and the pupa five days, making the total time for the development of the generation ten days. The larvæ molt twice, hence there are three distinct larval stages. There is thus abundance of time for the development of twelve or thirteen generations in the climate of Washington every summer. The periods of development vary with the climate and with the season, and the insect hibernates in the puparium condition in manure or at the surface of the ground under a manure heap. It also hibernates in houses as adult, hiding in crevices.

The number of eggs laid by an individual fly is so large, that the enormous numbers in which the insects occur are easily accounted for, especially when we consider the abundance and universal occurrence of appropriate larval food. In order to ascertain the numbers in which house-fly larvæ occur in horse-manure piles, a quarter of a pound of rather well-infested horse manure was taken on August 9, and in it were counted 160 larvæ and 146 puparia. This would make about 1200 house flies to the pound of manure. This, however, cannot be taken as an average, since no larvæ are found in perhaps the greater part of ordinary horse-manure piles. Neither does it show the limit of what can be found, since about 200 puparia were found in less than 1 cubic inch of manure taken from a spot 2 inches below the surface of the pile where the larvæ had congregated in immense numbers.

Movements of Flies. Most writers claim that flies do not travel far from the locality in which they breed, and little is known as to what distance they may cover. A single stable in which a horse is kept will supply house flies for an extended neighborhood. Packard thinks that flies can scent their food for several miles and may fly 20 or 30 miles a day if aided by winds. Undoubtedly the wind plays the greatest part in these long journeys of flies, and there seems to be good reason to believe that most flies do not travel far from the vicinity of their breeding places.

Flies and Temperature. Flies, like all insects, are most active in warm weather. On cold days, especially in the autumn, they become dormant and seek sheltered spots and warm places.

In order to determine the time of greatest prevalence of flies in New York City, Mr. D. D. Jackson made some interesting observations during the summer of 1907, in connection with a report to the Merchants' Association.

Many cages were placed in different parts of the city, especially along the water-front, and the number of flies caught at each place was counted daily. The following figures show the relative prevalence of flies at one of the fly-cage stations in Brooklyn.

Date. Week Ending —	Number of Flies Caught During the Week.	Date. Week Ending —	Number of Flies Caught During the Week.
May 4 . . .	0	Aug. 17 . . .	1165
11 . . .	0	24 . . .	435
18 . . .	1	31 . . .	99
25 . . .	3	Sept. 7 . . .	584
June 1 . . .	2	14 . . .	888
8 . . .	8	21 . . .	592
15 . . .	34	28 . . .	182
22 . . .	75	Oct. 5 . . .	52
29 . . .	244	12 . . .	47
July 6 . . .	921	19 . . .	51
13 . . .	2696	26 . . .	32
20 . . .	4165	Nov. 2 . . .	22
27 . . .	5727	9 . . .	7
Aug. 3 . . .	6224	16 . . .	0
10 . . .	3926		

Longevity of Flies. The longevity of flies is not well known. It is said that in the open flies may live a season, but that when confined in jars and cages they often do not live more than a week or ten days. It is said also that flies which have been infected with certain disease germs, as for instance, the bacilli of anthrax and tuberculosis, succumb more quickly than others not infected kept under the same conditions.

Means of Prevention. The problem of preventing the house fly from breeding has not yet been solved. Experiments have been made to destroy the maggots in horse manure by the use of kerosene, crude oil and chloride of lime, but the results have been only moderately successful. And at the present time the best method of avoiding the fly nuisance appears to be to build for the reception of stable manure large and tightly closed pits, well ventilated and screened, and so constructed that little direct light may enter.

Box privies are a nuisance from many points of view and are dangerous as breeding places of flies. If used at all they should be conducted on the earth-closet principle, and a free use of earth and powdered lime should be made.

Howard says that "people living in agricultural communities will probably never be rid of the pest, but in cities, with better methods of disposal of garbage and with lessening of the number of horses and stables consequent upon electric street railways and automobiles, the time may come before long when window screens may be discarded. Absolute cleanliness will always result in a diminution of the numbers of the house fly. Horse manure should be gathered and removed promptly, both from streets and from stables; garbage should be collected frequently; and all forms of excrement, dead animals and decaying organic matter of every description promptly taken care of."

APPENDIX III.

THE ESTIMATION OF POPULATION.

IN most countries a general census is made once in ten years. In the United States this is done in those years which are divisible by ten, that is, in 1880, 1890, 1900, etc., but in England and in Canada the general census is taken in the year following that, that is, in 1891, 1901, etc. In many of the states an intermediate census is taken between the federal censuses, that is, in 1895, 1905, etc. In some cities censuses are taken each year, but this is not common, although an annual record is often kept of the number of school children, the number of voters, the number of houses, etc., which are useful in making approximate estimates of the population.

The records of the United States census are published by the Census Bureau of the Department of Commerce and Labor, and various bulletins containing them can be obtained by addressing the Director of the Census Bureau, Washington, D.C.

In the censal years the exact figures given by the census should be used in calculating death-rates, but in the years between censuses it is necessary to estimate the population. There are various ways of doing this, but the one most commonly used is based on the assumption that during the period between the two censuses the population increases gradually, so that the estimate merely involves the application of the rule of three. Thus, if the population of a certain town was 10,000 in

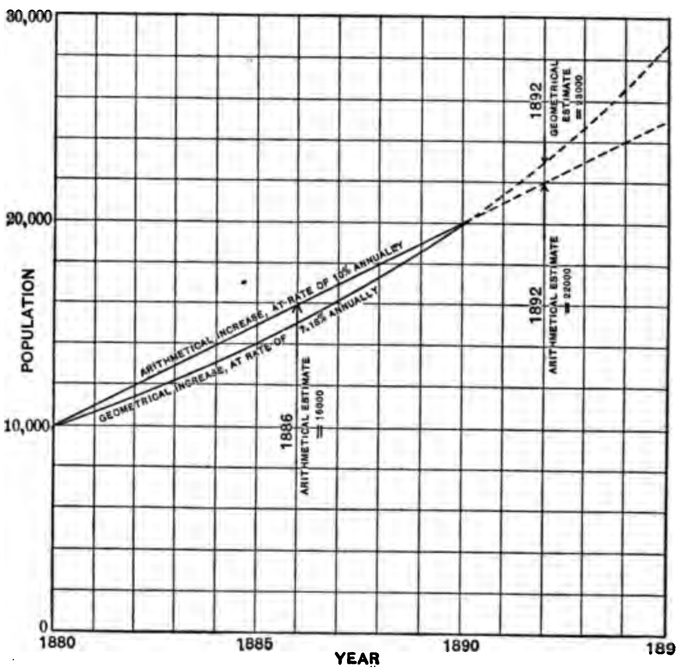


FIG. 50.

Diagram Showing the Arithmetical and Geometrical Methods of Estimating Population.

1880, and 20,000 in 1890, the estimated population in 1887 would be 17,000.

It is somewhat more difficult to correctly estimate populations in the years following a census, for, in this case, there is but one fixed population to reckon from.

There are two methods commonly used for estimating this extra-censal population, — the arithmetical and the geometrical. The arithmetical method, which is the one used by the United States Census Bureau, assumes that the annual increase in population after the censal year is the same as the average annual increase in population during the period between the last two censuses. Thus, in the town above mentioned, where the population in 1880 was 10,000 and in 1890, 20,000, the estimated population for the year 1892 would be 22,000. The geometrical method is based on percentage increase and assumes that the annual percentage increase in population in the years after the census is the same as the average annual increase in the period between the last two censuses. Thus, in the town referred to, the population increased 100 per cent between 1880 and 1890, which would be 7.18 per cent per year. If this rate were continued after 1890, then the population in 1891 would be 21,000 and in 1892, 23,000.

The formula for computing population in this way is: $P_x = P_c\,(1 + r)\,n$ in which P_x is the population desired, P_c the population given by the last census, n the number of years since the last census, and r the rate of increase. This is the same formula as that for compound interest.

In any estimate of this sort it is necessary to take into account local conditions, as these may be such as to make the application of either formula untrustworthy. Often the data showing the increase in the number of school children, the number of houses, etc., may be used as a guide in estimating populations outside of the census returns. It is particularly necessary not to place undue confidence upon formulæ in the case of rapidly growing towns or in communities where, through the introduction of manufacturing or some other great cause, there have been unusual changes in the population.

The United States Census Bureau now prepares annual estimates of population for all the large cities of the United States, that is, for those which have a population of 30,000 or more, and by reason of their official character these estimates are more and more coming to be used for the purpose of calculating death-rates.

In studying the records of death-rates in published reports, one should be careful to find out what basis of population was used in calculating them. For instance, — a death-rate for the year 1899 might be based upon a population estimate nine years after a census. The census of the following year might show that this estimated population was far from the truth, and that some other population should have been used. In studying old records, therefore, it is wisest to recalculate the rates, using the number of deaths as given and the new estimates of population made in the light of later census returns. To this end the published typhoid statistics of a city should include the actual number of deaths as well as the death-rates, or if the latter only are given, the population used in computing them should be stated clearly.

It is customary to use but a single figure for the population for any one year, and not to make any difference between months. The estimated population in the middle of a year is taken as the population for the entire year.

APPENDIX IV.

CORRECTED DEATH-RATES.

(From the Annual Report of the Massachusetts State Board of Health, 1902.)

THE State of Massachusetts has become so densely settled, so far as relates to its urban population, as to require a better method of computing the death-rates of large cities than that which is usually employed, when it is desirable to compare the death-rates of such cities with each other.

The following tables are presented for the purpose of showing the method of comparing the death-rates of different cities with each other, when the conditions as to the relative numbers of persons of different sexes and ages are not the same in each. The crude or recorded death-rate of any city for a given year, as obtained by comparing the existing population with the number of deaths in the year, may be compared with the death-rate of the same city for any other year or series of years, but it cannot be compared with that of another city, for the same year, unless the populations of the two cities have an identical relative distribution of the population by sexes and ages.

For example: the crude death-rates of the older cities and towns of the Atlantic sea-coast cannot properly be compared with those of new western cities, in which the relative number of persons of young and healthy ages is in excess of that in the former cities, while the population at advanced ages is also correspondingly smaller. For this reason the registrar-general of England has devised the method of referring the figures of different communities, cities and towns to some standard population, such as that of the country at large, or, as advised by other experts, to that of some very healthy population, like that of Sweden.

In the following table the population and deaths in the State at large are assumed as a standard, and the death-rates of the cities are compared with this standard. The method is fully explained in the last edition of Newsholme's "Vital Statistics."

The statistics of the year 1900 are here selected for presentation because the census enumeration was taken in that year. The data for sexes and ages, however, were only published for cities having a population of 25,000 or more in each. This includes 20 of the large cities of Massachusetts.

In certain cities the death-rate is unfavorably influenced by the presence of public and private institutions, in which a considerable number of non-resident patients are treated whose deaths should not be credited to the death-rate of those cities. An allowance has therefore been made of 419 deaths of such non-residents in Boston, of 119 in Worcester, of 79 in Taunton, and of 90 in Chelsea, all of which occurred in sixteen public and private institutions during the census year 1900.

For the purposes of this comparison a mean annual mortality of the State by ages and sexes for the three years 1899, 1900 and 1901 was calculated and applied to the population of each city in this group. This mean annual rate for each sex and age is shown in the following table: —

DEATH-RATES BY SEXES AND AGES. 1899–1901.

Ages.	Males.	Females.	Persons.	Ages.	Males.	Females.	Persons.
0– 5. . .	58.41	48.00	53.21	25–35. . .	7.96	7.31	7.63
5–10. . .	4.74	4.60	4.67	35–45. . .	10.48	9.42	9.95
10–15. . .	2.84	2.88	2.86	45–55. . .	16.26	14.20	15.21
15–20. . .	4.70	4.43	4.56	55–65. . .	30.96	26.51	28.59
20–25. . .	6.71	5.94	6.30	65 + . . .	88.60	82.78	85.35

From this table it appears that the death-rate at each age period between 5 years and 55 years was less than that of the State for all ages (which was 17.48 for the three years). Under 5 years and over 55 the death-rate is much higher than the combined death-rate of the State. If, therefore, the proportion of the total population living at different ages differs much in different cities or communities, then the total death-rates at all ages will also differ, independently of sanitary conditions.

The same rule applies to sex distribution. At all of the age periods, except ages 10–15, the female death-rate is lower than that of the male; hence an excess of females also tends to lower the general death-rate irrespective of sanitary conditions.

CENSUS OF 1900.

Ages.	Age Distribution of Population of					
	Massachusetts.		Holyoke.		Salem.	
	Males.	Females.	Males.	Females.	Males.	Females.
0– 5 years	505	501	610	618	530	520
5–10 years	457	456	550	556	506	473
10–15 years	407	411	480	498	411	427
15–20 years	411	437	448	525	405	449
20–25 years	461	534	454	627	449	519
25–35 years	921	955	849	972	842	920
35–45 years	704	708	658	643	631	710
45–55 years	470	492	398	411	448	523
55–65 years	292	334	216	244	286	377
65 years and over	224	286	83	140	220	328
Unknown	23	11	12	9	13	13
	4,875	5,125	4,758	5,242	4,741	5,259
	10,000		10,000		10,000	

To illustrate this principle the foregoing table is presented, containing the distribution of the population by sexes and ages in the State at large, and in the two cities, Holyoke and Salem.

In Holyoke the combined population at ages 0–5 and all over 55 constituted 19.1 per cent of the whole population, while that of Salem at the same ages was 22.6 of the whole. In the case of

Holyoke the percentage of the population at these ages was less than that of the State for the same ages, notwithstanding its high birth-rate, but its population at advanced ages is relatively small, as is usually the case in comparatively new cities. In Salem, a much older city, the population under 5, and also that which is over 55, is greater than that of the State at the same ages, thus favoring a higher death-rate in Salem and a lower one in Holyoke than that of the State at large.

The method of correcting the death-rates for sex and age distribution is shown in the following tables: —

RECORDED AND CORRECTED DEATH-RATES PER 1,000 PERSONS LIVING IN MASSACHUSETTS CITIES OF MORE THAN 25,000 INHABITANTS IN 1900.

Cities in the Order of Their Corrected Death-Rates.	1 Standard Death-rates.	2 Factor for Correction for Sex and Age Distribution.	3 Recorded Death-rates. 1900.	4 Corrected Death-rates. 1900.	5 Comparative Mortality Figure.
MASSACHUSETTS	17.48	1.000	18.23	18.23	1.000
Brockton. . . .	16.27	1.074	13.85	14.87	0.816
Malden	17.02	1.027	14.53	14.92	0.818
Newton	17.06	1.024	15.01	15.37	0.843
Haverhill . . .	17.67	0.989	15.55	15.38	0.844
Somerville . . .	17.30	1.010	15.67	15.83	0.868
Fitchburg . . .	17.02	1.027	15.67	16.09	0.883
Chelsea	17.77	0.984	16.42	16.16	0.886
Lynn	16.80	1.040	15.91	16.55	0.908
Gloucester . . .	17.33	1.009	17.00	17.15	0.941
Cambridge . . .	16.54	1.056	16.54	17.47	0.958
Springfield . . .	17.31	1.010	18.93	19.12	1.049
Salem	17.95	0.974	19.86	19.34	1.061
Worcester . . .	16.56	1.056	18.33	19.36	1.062
Taunton	16.89	1.035	19.43	20.09	1.102
Lowell.	16.07	1.088	19.48	21.19	1.163
Boston.	16.26	1.075	20.08	21.59	1.184
New Bedford. .	17.07	1.024	21.19	21.70	1.190
Lawrence . . .	16.09	1.086	20.40	22.15	1.215
Fall River . . .	15.90	1.099	21.53	23.66	1.297
Holyoke	15.55	1.124	21.96	24.68	1.354

In this table the Standard Death-rate signifies the death-rate at all ages calculated on the hypothesis that the death-rates at each of the ten age periods in each city were the same as in Massachusetts during the three years 1899–1901, the death-rate at all ages in Massachusetts during that time having been 17.48 per 1,000. The Factor for Correction is the figure by which the crude or recorded death-rate should be multiplied in order to correct for variations of sex and age distribution. The Corrected Death-rate is the recorded death-rate multiplied by the Factor for Correction. The Comparative Mortality Figure represents the Corrected Death-rate in each city, compared with the Recorded Death-rate at all ages in Massachusetts in 1900 taken as 1000.

The figures in this column (5) may be read as follows: after making approximate corrections for differences of age and sex distribution, the same number of living persons that gave 1,000 deaths in Massachusetts in 1900 gave 816 in Brockton, 818 in Malden, 1,354 in Holyoke, etc.

The first column in the table is obtained by assuming that the mean mortality in Massachusetts in the three years 1899–1901 prevailed in each city. The age and sex distribution of each of these cities at the census of 1900 being known, the mean mortality in Massachusetts in 1899–1901 is applied to the population thus constituted, and the result is the series of death-rates in column 1. The differences in the death-rates of the cities in this column are therefore caused only by the difference in the age and sex distribution of their inhabitants.

The following example shows the method of obtaining these standard death-rates: —

The population of Holyoke in 1900 was 45,712; the total number of calculated deaths in Holyoke was 711; the standard death-rate was, therefore, $\frac{711 \times 1000}{45,712} = 15.55$.

Now the mean annual death-rate of Massachusetts in 1899–1901 was 17.48. This should be the same as the calculated death-rate for Holyoke, which was obtained by applying the mean annual death-rate of Massachusetts at the different age groups to the population of Holyoke at the same ages.

Ages.	Mean Annual Death-Rate in Massachusetts, 1899–1901, per 1000 Living at Each Group of Ages.		Population of Holyoke. 1900.		Calculated Number of Deaths in Holyoke.	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5 years	58.41	48.00	2,787	2,824	163	135
5–10 years	4.74	4.60	2,514	2,542	12	12
10–15 years	2.84	2.88	2,194	2,276	6	6
15–20 years	4.70	4.43	2,048	2,400	10	11
20–25 years	6.71	5.94	2,075	2,866	14	17
25–35 years	7.96	7.31	3,881	4,445	31	32
35–45 years	10.48	9.42	3,006	2,940	31	28
45–55 years	16.26	14.20	1,818	1,879	30	27
55–65 years	30.96	26.51	985	1,113	30	29
65 years and over	88.60	82.78	381	642	34	53
Unknown	...	...	55	41	...	...
	...	...	21,744	23,968	361	350
			45,712		711	

But the calculated or standard death-rate for Holyoke is lower, as shown above, which must arise from the fact that the distribution of ages and sexes in the Holyoke population is more favorable than in the State at large.

The standard death-rate in Holyoke, being lower than that of the State, must be raised in a certain ratio in order to bring it into comparison with that of the State. It must be increased in the proportion of 15.55 to 17.48.

The factor for correction for age and sex distribution, by which the recorded death-rate of Holyoke must be multiplied in order to make it comparable with that of Massachusetts is

$\frac{17.48}{15.55} = 1.124$. We have employed a triennial correction figure as a constant, having the census year 1900 as the middle year of the three. Any error which may be due to the use of a triennial correction figure instead of a special correction figure for a single year is so small that it may practically be disregarded. By multiplying the recorded death-rates in column 3 by the factors for correction, the corrected death-rates in column 4 are obtained. These are the death-rates which would have been recorded in each town had its population been identical, so far as age and sex distribution are concerned, with the population of Massachusetts.

APPENDIX V.

BACTERIOLOGICAL DESCRIPTION OF THE TYPHOID BACILLUS.

NAME.

B. *der Abdominal typhus*, Eberth: Virchow's Archiv. LXXXI, 1880.

B. *typhosus*, Zopf: Spaltpilze, 1885.

MORPHOLOGY.

Slender rods, with rounded ends, occasionally occurring as filaments, actively motile.

Length, 1 to 3 μ; diameter 0.5 to 0.8 μ.

Flagella, peritrichiate, 8 to 12 in number, long and undulating.

Spores never have been observed.

Stains readily with watery dyes.

Does not stain by Gram's method.

Killed by exposure to a temperature of 65° C. for ten minutes.

Aërobic and facultatively anaërobic.

NUTRIENT BROTH.

Slightly turbid; no pellicle.

GELATIN PLATE.

Deep colonies: round, gray to yellowish brown, entire.

Surface colonies: at first small, punctiform, becoming flat, roundish, gray, glistening, with irregular borders; microscopically, colorless, translucent, becoming grayish yellow, darker in the center, marmorated; border undulate to lobate; strongly refracting.

No liquefaction.

Surface growth, thin, whitish, irregular.

Gelatin Stab.

Line of puncture, filiform, beaded.
No liquefaction.

Milk.

No coagulation. Slight acidity, which occasionally changes after a time to alkalinity.

Litmus Milk.

Slight acid reaction; variable, no coagulation.

Potato.

Growth a pure white glistening streak, thin or scarcely visible.

Agar Slant.

Growth thin translucent, smooth, slimy, spreading, — well marked after 24 hours at 37° C.

Lactose Litmus Agar.

Color of growth bluish.

Nitrate Broth.

Nitrates reduced to nitrites.

Indol Production.

Indol not produced, or, if so, only a small amount.

Fermentation Tests.

Dextrose broth. No gas produced; little acid.
Lactose broth. No gas produced; no acid.
Saccharose broth. No gas produced; no acid.
Maltose broth. No gas produced; some acid.
Mannite broth. No gas produced; some acid.

Neutral Red Glucose Broth. No color change.

Reaction with Anti-typhoid Serum.

Readily agglutinated by highly diluted serum. It is best to use a powerful serum obtained from an immunized animal rather than from the blood of a typhoid patient.

PFEIFFER'S TEST.

This consists in injecting a ten times fatal dose of the bacillus, together with a small quantity of serum from an animal highly immunized against the typhoid bacillus, into the peritoneal cavity of a guinea pig. If the suspected organism is the typhoid bacillus, then the bacilli are converted into granular masses (tested by removal and examination of a little peritoneal fluid after half and after one hour), and the animal does not die, while a control animal, injected with the bacillus alone, dies.

SIMILARITY TO OTHER BACTERIA.

The typhoid bacillus in many respects resembles other bacteria, most of which are of intestinal origin. One of these is bacillus coli communis, or B. coli, an almost constant inhabitant of the intestines of warm-blooded animals. Because of this fact it is an organism commonly used as an index of fecal pollution. Complete descriptions of these various allied organisms are given in most works on Bacteriology.

APPENDIX VI.

TESTS FOR THE DIAGNOSIS OF TYPHOID FEVER.

THE WIDAL TEST.

(*From a Circular of Information issued by the Department of Health of the City of New York.*)

THE investigations of Grüber, Widal and others, published in 1896, show that the blood of persons suffering from or having recently had typhoid fever, contains, as a rule, after the fifth day of the disease, substances which when added to a broth culture of the typhoid bacilli arrest the characteristic movements of these organisms and cause them to become clumped together in masses.

It has been further shown that occasionally the blood of persons suffering from other diseases possesses this peculiar property; but that when the agglutinating substances are present in these it is in relatively small amount. These substances are also occasionally present in small amount in other diseases and even in health. The reaction is, therefore, a quantitative rather than a qualitative one.

The results of a very large number of examinations made here in New York and elsewhere show, that if the blood contains agglutinating substances in sufficient amount to cause a prompt and marked reaction, when one part of serum or blood solution is added to *twenty parts* of a culture of the typhoid bacillus, the presence of a previous or existing typhoid infection may, for diagnostic purposes, be practically considered as established.

In estimating the diagnostic value of a negative result from this test, we must remember that the reaction is rarely, if ever, present until at least five days after the appearance of symptoms; that it is occasionally absent in cases of typhoid fever until the third or fourth week, or even until convalescence is established; that when developed it may disappear after a few days; and that no definite relation between the severity of the disease and the degree and time of development of the substances causing the reaction has been established. For these reasons a single negative result in any suspected case only renders doubtful the existence of typhoid fever. In those cases in which the reaction is absent after the ninth day, it may be reasonably assumed that the large majority will not prove to be typhoid fever, and the absence of the reaction in all of several different cases of a suspected group, or after repeated examinations in any single case, affords evidence of very decided value in excluding the diagnosis of typhoid fever.

Either dried blood or the serum obtained from a blister may be sent for examination. Outfits for preparing dried blood specimens may be obtained at any of the stations of the Department of Health, a list of which will be forwarded on request. Serum outfits may be obtained at any of the Department's Borough offices, or will be mailed on application.

Directions for Preparing Specimens of Blood. The skin covering the lobe of the ear is thoroughly cleansed and then pricked with a clean needle deeply enough to cause several drops of blood to exude. Two large drops are then placed on the glass slide, one near either end, and allowed to dry in the air without being spread out on the surface of the slide. The specimens should never be heated or treated with any chemical fixative. After drying, the slide is to be replaced in the holder and returned in the addressed envelope to a culture station, or mailed to the laboratory. The blank giving the history of the case must be filled out in full and forwarded with each specimen. The data thus obtained are for record.

Directions for Obtaining Specimens of Serum from Blisters. The shield (designed to protect the blister from rupture) is applied to the skin somewhere on the anterior portion of the body. The piece of canthos plaster is then fixed within its center. After

10 to 12 hours the shield is removed and one of the ends of the small glass tube accompanying the outfit is introduced into the blister. The tube, both ends of which should be open, should be held so that the end inserted is higher than the other, to allow the serum to run into it. After the tube has been nearly filled, it is removed and the ends sealed by holding them a moment in a gas flame. Care must be observed not to heat the middle portion of the tube, and thus coagulate the serum. The tube so prepared is then placed in the wooden box and returned in the addressed envelope to a culture station, or mailed to the laboratory.

A report on the results of the examination will be telephoned to the attending physician early on the following day, where his telephone number can be ascertained. Reports are mailed by 1 P.M. each day, and should reach their destination the same evening.

Laboratory Technique. A culture of typhoid fever bacilli is obtained from an authenticated case of typhoid fever, and this must be selected with care. Not all races of typhoid bacilli give equal results, and by a process of selection a culture must be found that gives the best results in the largest number of cases. Having obtained a satisfactory culture it should be kept in a virile condition by frequent transfers to agar tubes. For use fresh bouillon cultures should be used, — that is, sub-cultures less than twenty hours old. The reaction of the medium shall be not far from the neutral point.

A drop of the blood to be examined is placed upon a glass slip, with nine drops of sterile water around it, and the whole stirred with a sterile platinum wire until the blood has been well mixed through the mass. This gives a 1:10 dilution. Occasionally higher dilutions are used.

A drop of this diluted blood is then added to a drop of the culture medium, containing the living typhoid bacilli. This gives a dilution of 1:20, the dilution generally used. The cover glass is then sealed with vaseline and placed under the microscope, using a one-sixth inch objective, and the material examined as a "hanging drop," at intervals for about half an hour.

In a typical positive reaction the bacilli lose motility and group themselves in clusters, or clumps. This agglutination of the bacilli is indicative that the blood is derived from a person who has or who has recently had the disease. Agglutination may occur in some cases in high dilutions; in others, only in low dilutions. But low dilutions may sometimes show positive tests in the case of other diseases, and even in the case of well persons; hence the test is not always final and deciding. As a rule, however, positive tests obtained using a dilution of 1:20 indicate a positive diagnosis.

For further data concerning this test, and the agglutinating effects of the paratyphoid bacillus, the bacillus of dysentery, etc., the reader is referred to the recent works on pathological bacteriology.

Ehrlich's Diazo Reaction in Urine. The presence in the urine of Ehrlich's diazo reaction for typhoid fever furnishes an early and valuable aid in the diagnosis of typhoid fever.

The test is performed in the following manner: Equal parts of the suspected urine and the following solution (saturated solution of sulphanilic acid in 5 per cent hydrochloric acid 40 parts; 0.5 per cent solution of sodium nitrite 1 part) are mixed and well shaken. On the addition of a few drops of ammonia a brilliant rose pink color should appear, if the case be one of typhoid fever. The twelve-hour sediment is also characteristic, consisting of a dirty gray lower layer and a narrower dark olive green upper layer.

This reaction is present in the urine of a great majority of all cases of typhoid fever at some time in their course. It is found earlier than the Widal reaction in the blood, appearing on from the third to the sixth day of the disease. The intensity and date of appearance of the reaction appear to have no relation to the severity of infection. In a number of instances the diazo reaction has been present in undoubted cases of typhoid fever in which no Widal reaction was at any time obtainable from the blood. No case has so far been observed in which the Widal reaction was present and the diazo reaction absent. The reaction is present in its greatest intensity at about the tenth day of the disease. It often disappears at the end of the second week, and is almost invariably absent when complete defervescence is reached. In relapses the reaction usually reappears, but if the reinfection is mild, it may be absent. In second or third attacks of the disease, occurring after intervals of months or years, the reaction is present just as in primary attacks. It is also present in certain other conditions; these are severe scarlet fever and measles, acute miliary tuberculosis, and general sarcomatosis or carcinosis. With the exception of miliary tuberculosis, however, the above conditions are usually readily distinguishable from typhoid fever.

Examination of the Blood for the Typhoid Bacillus. Coleman and Buxton's blood test is described on page 322.

By the use of this test, the diagnosis of the disease can be made at an earlier stage than with the Widal test alone.

APPENDIX VII.

THE BACTERIOLOGY OF THE BLOOD IN TYPHOID FEVER. AN ANALYSIS OF 1602 CASES.[1]

By Warren Coleman, M.D., Professor of Clinical Medicine, Cornell University Medical College, and Assistant Visiting Physician to Bellevue Hospital, New York, and B. H. Buxton, M.D., Professor of Experimental Pathology, Cornell University Medical College, New York.

DURING the last six years we have made bacteriological examinations of the blood in 123 cases of typhoid fever in the wards of the Second Medical Division of Bellevue Hospital. In 1904 we published an analysis of 604 cases of typhoid fever (for the most part collected from the literature) in which the blood had been examined bacteriologically. Seventy-five per cent of these cases, examined at all stages of the disease, showed the presence of the typhoid bacillus. Bacteriological examinations of the blood of typhoid and suspected cases have been made routine practice in many hospitals, and the number of cases reported to date, including our own, reaches a total of 1602. The present analysis includes all the cases in our former paper, except the reports of individual cases.

Methods. We usually draw 10 cubic centimeters of blood into an all-glass syringe from a vein at the bend of the elbow. In our earlier experiments (1901 to 1903) we used broth flasks, putting 2 to 3 cubic centimeters of blood into each 100 cubic centimeters of broth. Later, on learning that Busquet and other French authors had had extraordinary success by using very large quantities of broth, we followed their method of dilu-

[1] From the *American Journal of the Medical Sciences*, June, 1907.

ting each cubic centimeter of blood in about 200 cubic centimeters of broth, but the results were not appreciably better than before. Since August, 1906, however, we have had very marked success with ox-bile, as recommended by Conradi. Ox-bile not only prevents coagulation, but inhibits the bactericidal action of drawn blood and affords an excellent culture medium for typhoid bacilli. Our tests on this point have fully confirmed the previous observations of Conradi, Kayser and others.

The method followed has been to take ox-bile 90 cubic centimeters, glycerin 10 cubic centimeters, and peptone 2 grams. The mixture is distributed into small flasks, 20 cubic centimeters in each, and sterilized. Three of these flasks are used for each examination, about 3 cubic centimeters of blood being run into each. The flasks are then incubated, and the next morning streaks are made from each flask over the surface of a litmus-lactose-agar plate. If microörganisms are present, a growth may be observed in five or six hours. If the growth does not redden the medium and is found to be a bacillus resembling the typhoid organism, it is tested for the Widal reaction with immune serum. By this procedure we are often able to determine if the case is one of typhoid fever or not within twenty-four hours after drawing the blood.

Of 1602 tabulated cases, 1197, or 75 per cent, gave a positive result. The examinations were made at all stages of the disease and by different methods. Since in our experience the bile method[1] is the only one which may confidently be depended upon, such a large percentage of positive results goes far to prove that the bacillus is present in the blood in practically all cases of typhoid fever.

Analysis of the Cases by Weeks. The day of the disease upon which the examination was made is mentioned in 1137 cases only. To be more exact, this represents the number of examinations, not of cases, for in many instances more than one examination was made in a case.

First Week. Of 224 examinations in the first week of the

[1] We have not tried the glucose method of Epstein.

disease, 200 (89 per cent) were positive. The earliest positive result has been reported by Widal, who recovered the bacillus from the blood on the second day of the disease. The reported positive results become more frequent as the end of the first week is approached, only, we believe, because the disease is not suspected earlier, and the examinations made, or because the cases do not come under observation.

Second Week. Of 484 examinations made in the second week of the disease, 353 (73 per cent) were positive.

Third Week. Of 268 examinations made in the third week of the disease, 178 (60 per cent) were positive.

Fourth Week. Of 103 examinations made in the fourth week of the disease, 39 (38 per cent) were positive.

After the Fourth Week. Of 58 examinations made after the fourth week of the disease, exclusive of relapses, 15 (26 per cent) were positive.

Very few statements are made concerning the clinical histories of the cases in and after the fourth week, though some of them are reported as severe and of long duration. As in our first analysis, the percentage of positive results is greatest in the first week and steadily declines thereafter.

We have already called attention to the remarkably successful results of Busquet and others, who recovered the bacillus from the blood in approximately 100 per cent of their cases. Our results since the adoption of the bile method have been equally successful, standing out in marked contrast to those with broth. In all we have used this method in 34 cases. As a rule, the blood was examined as soon as a case of fever without obvious cause entered the hospital, and before the diagnosis was established. Six of these 34 cases were diagnosticated ultimately as certainly not typhoid fever; 3 of the cases pursued the clinical course of typhoid fever, but gave neither a positive blood culture, nor a positive serum reaction against any member of the typhoid-colon group. In fact, after examinations of urine, feces, opsonic index, and injections of tuberculin, a satisfactory diagnosis could not be made. It seems only fair to exclude these cases. One case ran an eleven-day temperature, the maximum being 101 degrees, but for the most part ranging between 99 and 100 degrees. The first blood culture was taken on the eighth day. There was a difference of opinion as to the diagnosis. The patient had an old tuberculous process at one apex. This case likewise may be fairly excluded. We made three examinations of his blood.

The remaining 24 cases were typhoid fever clinically and by serum reaction and all gave positive bacteriological results. The examinations were made from the fifth to the twenty-first day in a long-duration case.

The various series of cases in the table giving approximately 100 per cent of positive bacteriological results are too numerous to be accidental. They compel the conclusion that the typhoid bacillus is present in the blood in every case of typhoid fever and that failure to recover it is due to error of technique. The diminishing percentages of the larger analysis in the later weeks of the disease do not indicate, then, that the bacillus has disappeared from the blood in the negative cases, but point rather to diminishing numbers of bacilli, whose presence imperfect methods have failed to reveal. All investigators except Conradi are agreed that the bacillus disappears from the blood at or about the time the temperature falls to normal. Conradi claims that the bacillemia persists into convalescence. We have repeatedly examined the blood in the last day or two of the febrile period and not once have we recovered the bacillus. Therefore, it seems probable that the typhoid bacillus is not only present in the blood in every case of typhoid fever, but that it is present throughout the course of the disease, or at least to within a day or two of complete defervescence.

The Significance of the Bacillemia. If future observations confirm the conclusion that the typhoid bacillus is present in the blood of every case of typhoid fever throughout its course, the current conception of the pathogenesis of the disease should be modified. Typhoid fever can no longer be regarded simply as an infection of the body with typhoid and related bacilli

(Bacillus paratyphosus, etc.). The typhoid bacillus may be present in the body and actively growing, yet the patient not have typhoid fever. It has been shown, for example, that the bacillus may live and multiply in the intestine of healthy persons. The patient is infested and a menace to others, but is not infected. The number of cases of biliary infection with the typhoid bacillus, without a previous or existent typhoid fever, is fairly large and is increasing. At least two cases of cystitis, caused by the typhoid bacillus in persons without a history of typhoid fever, have been recorded. (There is little probability, however, of the absorption of endotoxins in any quantity in cholecystitis and cystitis). In the post-typhoid bone and other inflammatory lesions the lodgment and growth of the bacillus do not produce the characteristic symptoms of typhoid fever, in spite of the fact that large amounts of endotoxin should be liberated and absorbed when the abscesses are multiple. The very term used to describe these conditions, "post-typhoid," indicates that the typhoid fever *per se* has subsided. The temperature curve conforms to the so-called septic type.

Therefore, it seems that to produce typhoid fever the bacillus must not only be present in the body and growing, but that it should grow in a situation whence it has free access to the blood. In our first paper we expressed the opinion that in typhoid fever the earliest and principal seat of infection is the blood, and that the disease should be regarded as a bacillemia. From the work done by one of us on the absorption of the typhoid bacillus from the peritoneum, and from the fact that in typhoid fever the lymph nodes and spleen contain such enormous numbers of bacilli, we are disposed to modify this view and to conclude that in typhoid fever the bacillus first finds its way from the alimentary tract to the lymphopoietic system, including the spleen, where it develops chiefly and from which it invades the blood stream. We think it doubtful whether the bacillus multiplies in the blood, but rather that its presence there represents simply an overflow from the lymph organs. Under this interpretation the presence of the bacillus in the blood does not constitute a true septicemia.

The absorption experiments above referred to also indicate that destruction of the typhoid bacilli proceeds most rapidly in the blood. This observation, together with the fact that the bacillemia persists throughout the disease, suggests the following view of the pathogenesis of typhoid fever: That the disease is caused by the destruction of vast numbers of bacilli in the blood, with the liberation of their endotoxins, and the consequent reaction on the part of the host. When the endotoxins are liberated elsewhere in the body, *e.g.*, in abscesses, the symptomatology is not that of typhoid fever.

This conception of the nature of typhoid fever is borne out by analogy. It is known that Bacillus paratyphosus may infect the intestine and produce the clinical picture of gastro-enteritis, but that when it invades the lymph organs and blood it produces a disease clinically indistinguishable from typhoid fever. Diplococcus lanceolatus and the various streptococci furnish similar analogies in that they produce different affections according to the regions they attack.

There is another matter to which we would call attention in this connection. The idea still prevails in some quarters that the course of typhoid fever may be influenced and even shortened by the use of intestinal antiseptics. Such opinion is based on an erroneous conception of the nature of typhoid fever. After invasion of the body proper by the bacillus the battle-ground shifts from the intestines to the blood, and the employment of intestinal antiseptics with the idea of controlling the disease is, to say the least, irrational.

The Relation of the Bacillemia to the Course and Types of the Disease. *Course.* The analysis of the cases in the various weeks of the disease suggests the following relation of the bacillemia to the course of typhoid fever: In the earlier stages the bacillus invades the blood in greatest numbers. Later, as the disease is approaching a favorable termination, the diminution in the number of bacilli in the blood is simply an index of less active development in the lymphatics and spleen. If the disease in any case pursues a long-duration course, that beyond the usual three weeks, the bacillus may be recovered from the blood as long as the temperature persists. We have isolated the bacillus late in such cases repeatedly. There appears then to be a definite relation in the evolution of typhoid fever between the symptoms and the bacillemia. The increasing intensity of the symptoms in the earlier period of the disease corresponds to active growth of the bacilli. They invade the blood stream in increasing numbers and are there destroyed. Then comes the stationary period, when the ratios of growth and destruction appear uniform. The steep-curve period corresponds to a diminishing bacillemia, and defervescence to the complete disappearance of bacilli from the blood. In other words, the duration of the febrile movement is measured by the persistence of the bacillemia. As already stated, Conradi is the only investigator who claims that the bacillemia continues into convalescence.

Ewing has expressed the opinion that "the degenerative changes in the liver, kidneys, and lymphoid organs, while initiated by the bacterial proteids, possess certain self-perpetuating tendencies," and therefore "typhoid fever is a combination of a specific bacterial intoxication and a somewhat peculiar auto-intoxication, the former element being more prominent early, the other later in the disease, but both developing simultaneously." We are unable to accept this conception of the pathogenesis of typhoid fever. It appears inconsistent with the facts developed by our studies. We maintain that exclusive of convalescence, which should be regarded as the period of repair, degenerative changes occur only in the presence of active growth and destruction of bacilli. We have shown that convalescence is established immediately upon the disappearance of the bacilli from the blood, and there are reasons to believe that it is not interrupted except as the result of a fresh growth of bacilli. While the bacilli disappear from the blood at or just before defervescence, it is improbable that all the bacilli in the body have been destroyed. Otherwise, relapses and post-typhoid inflammatory lesions would be impossible. Unless then it can be shown that the symptoms of typhoid fever would persist after the complete destruction of all bacilli in the body, we think that Ewing's position is untenable.

Types. The bacillemia apparently bears no relation to the type or severity of the disease except in so far as regards numbers of bacilli. The bacillus is found in the blood equally, but not with the same persistence, in the mild as in the severe cases, and in the cases of short as well as of long duration. We have found the bacillus, for example, in cases lasting ten, thirteen, and fourteen days, and on the twenty-seventh day of a long-duration case. The importance of the definite establishment of the nature of these short-duration cases can scarcely be overestimated from the epidemiological standpoint. The serum reaction has done much to clear up their diagnosis, but the final proof has remained for the bacteriological examination of the blood. We make only a brief reference to these cases here, as we shall deal with them at length in the near future.

Relapses. The blood has been examined bacteriologically by various investigators in 33 relapses. The typhoid bacillus has been recovered in 30 (90 per cent) of the cases. We suggested in 1904 that a relapse in typhoid fever is due to reinvasion of the blood by the bacillus. Reinvasion of the blood with destruction of the bacilli probably causes the symptoms of a relapse, but the underlying conditions which inaugurate active development of the bacilli after their growth has once been brought under control are unknown. We feel safe in asserting that a relapse is not due to reinfection with the typhoid bacillus from the intestine as the result of intestinal trauma brought about by dietary irregularities. We do not wish to intimate, however, that we believe the occurrence of a relapse is entirely independent of diet or to be understood as advocating a liberal diet in typhoid fever. We are not prepared as yet to express an opinion upon this subject.

The Relation of the Bacillemia to the Serum Reaction. In our former paper we stated that it would seem likely on *a priori* grounds that the typhoid bacillus is always present in the blood before the serum reaction develops, for the reason that endotoxins should be liberated before the agglutinins could be formed. The following table clearly illustrates the truth of this conclusion:

TABLE SHOWING RELATION OF BACILLEMIA TO SERUM REACTION.

Author.	Number of Cases.	Bacillus Found and Widal Reaction Negative.
Hirsh	100	23
Jochmann	30	5
Rolly	50	16
Duffy	88	18
Buxton and Coleman	123	32
	391	94

Of the 55 cases of Hirsh and ourselves, which showed the presence of the bacillus in the blood before the serum reaction could be obtained, 23 were in the first week, 26 in the second, and 6 in the third. The diagnostic value of these results in cases in which only one, or a few, serum tests have been made is important. A negative serum reaction may have no significance even in the third week of the disease. Moreover, Dr. Hastings has shown in some of our cases, especially those of short duration, that a positive serum reaction may be present for only two or three days. If the serum reaction had not been tested on those days, the result would have been recorded as negative throughout the disease. For the complete diagnosis of an obscure case by the serum reaction the tests should be made daily.

Conclusions. 1. The typhoid bacillus is present in the blood of every case of typhoid fever throughout its course.

2. The bacillemia in typhoid fever does not constitute a true septicemia, but it represents an overflow of bacilli from the lymphopoietic organs.

3. The clinical picture of typhoid fever results only from infection of the lymphopoietic organs by the typhoid bacillus, with

invasion of the blood stream and destruction there of vast numbers of bacilli.

4. The endotoxins of the typhoid bacillus are not cumulative in action, and convalescence from the typhoid fever *per se* is established within a few days after the disappearance of the bacilli from the blood.

APPENDIX VIII.

EXAMINATION OF WATER FOR THE TYPHOID BACILLUS.

The isolation of the typhoid fever bacillus from infected water is a matter of such difficulty that less than a dozen authentic cases of its finding are on record. Nevertheless, theoretically, it can be done, and it is not unlikely that the future may reveal some important developments in this direction. Savage, in his recent excellent work on the Bacteriological Examination of Water Supplies,[1] has described various methods that have been used. These may be found also in Prescott and Winslow's "Elements of Water Bacteriology."

There are three steps involved in the process: —

1. *Concentration*, whereby any typhoid bacilli that may be scattered through a large volume of water are brought together in a small volume within the compass of present methods of examination.

2. *Isolation* of the organism in pure culture.

3. *Identification* of the organism by the application of differential tests.

Concentration. A simple method of concentration is to filter a large quantity of the sample to be examined through a sterile Pasteur filter and brush the accumulated sediment into a small quantity of sterile water. This method is not satisfactory, as it increases all other kinds of bacteria in the same proportion.

The use of the centrifuge has been recommended in place of filtration, but it has no especial advantage. Sometimes chemicals are used to produce a coagulent that during its precipitation will entangle the bacteria and carry them to the bottom.

[1] Published by P. Blakiston's Son & Co.

Anti-typhoid serum has also been used in a somewhat similar manner.

Other methods depend upon the greater motility of the typhoid bacillus than most of the other bacteria likely to be found in water, and attempts have been made to separate the typhoid bacilli from the others by taking advantage of this characteristic.

Various forms of enrichment methods have been suggested, that is, certain substances are added to the water with the object of facilitating the multiplication of the typhoid germ, or of inhibiting the development of other forms. Phenol broth, caffeine, etc., have been used for this purpose; the latter with most success, but the sterilized ox-bile has been found to be more satisfactory than either.

Isolation in Pure Culture. For this stage of the process some kind of solid medium is necessary in connection with the method of plate culture. Among the media used are nutrient gelatine, nutrient agar, semi-solid media composed of both gelatine and agar, phenol agar, lactose litmus agar, bile-salt agar, neutral red agar, etc. The Drigalski-Conradi agar is more satisfactory than any. Savage [*loc. cit.*] describes the use of this medium as follows:

Drigalski-Conradi Agar. "This medium was primarily intended for the isolation of the typhoid bacillus from excreta; it is, however, of great value in water bacteriology. It is prepared as follows:

"(1) *Agar Preparation.* — To 3 pounds of finely-cut beef, add 2 liters of water; allow the mixture to stand until next day. Boil the expressed meat-juice for one hour and filter; add 20 grams peptone sicca (Witte), 20 grams nutrose, 10 grams sodium chloride, boil the whole again for one hour and then filter. Now add 70 grams bar agar, boil for three hours (or one hour in the autoclave), renders lightly alkaline (indicator, litmus-paper), filter, boil for half an hour.

"(2) *Litmus Solution.* — Litmus solution (Kubel and Tiemann), 260 cubic centimeters; boil for ten minutes; add 30 grams of chemically pure milk-sugar and boil for fifteen minutes. Add the hot litmus milk-sugar solution to the liquid agar solution (cooled to 60° C.); shake well; render it again faintly alkaline; then add 4 cubic centimeters of a hot sterile solution of 10 per cent water-free soda and 20 cubic centimeters of a freshly prepared solution of 0.1 gram crystal violet (B. Hochst) in 100 cubic centimeters warm sterile distilled water. The result is a meat-water peptone nutrose agar, containing 13 per cent litmus and 0.01 per 1,000 crystal violet. The medium can be kept in tubes, or in small flasks containing enough for three or four plates. It is sufficient to sterilize once in current steam for thirty minutes."

"The Petri dishes used should be large (diameter 15 to 20 centimeters), and about 20 to 25 cubic centimeters should be poured into each. The medium should never be less than 2 millimeters thick. After pouring, the plate should remain uncovered for at least one hour, until the steam has evaporated and the agar is quite stiff. A sterile glass rod bent near one end at right angles is used for smearing the plates. After the plates are spread they should remain open for at least half an hour, until the agar surface is completely dry. This, according to the authors, is important, moisture causing the colonies to run together. Saprophytic air organisms are said not to grow, on account of the crystal violet, so that air contamination does not take place."

"After fourteen to sixteen hours at 37° C. — twenty-four hours in some cases — the colonies can be distinguished from one another. The coli colonies are red, not transparent, and have a diameter of 2 to 6 millimeters, but considerable variation in size and degree of color are met with. The B. *typhosus* colonies are blue, with a violet tinge; they are transparent and resemble dew-drops, and have a diameter of 1 to 3 millimeters, seldom larger."

Identification. This stage of the process consists in ascertaining if the organism isolated conforms to the differential tests for typhoid fever in accordance with the characteristics set forth on page 314.

Regarding this process Savage says: —

" It is now generally advocated that all suspicious organisms should first be roughly tested as to their ability to be agglutinated by typhoid serum in moderate dilution. If no agglutination takes place, they may be at once rejected. If a positive reaction is obtained, cultural tests are carried out, while a more exact series of agglutination tests is made. In this way it is possible to greatly lighten the labor of examining a large number of suspicious colonies. The colonies under investigation are either at once examined or after subcultivation. For the first method a little of the colony is transferred to a cover-slip emulsified in a drop of broth, and an equal quantity of serum added, the whole test being carried out on the cover-slip. For the second method the colonies are inoculated into nutrient broth, and the agglutination tests performed next day, after growth has taken place. The latter is, on the whole, preferable. The broth cultures which show a positive result are then ready for further investigation; the others are rejected."

" Great as are the improvements which have taken place in the facility with which typhoid bacilli can be isolated from specifically infected excreta, with none of the different methods can it be said that the isolation of the bacillus from an infected water-supply is other than a difficult and unsatisfactory procedure, and only under very favorable conditions can success be hoped for."

"It is advisable to try several methods, and in the writer's opinion the following would probably be the most serviceable procedure:

"(*a*) Examine 5 to 10 liters by Drigalski's method."

"(*b*) Take 1 liter of the water and precipitate the organisms by one of the precipitation methods. The precipitated organisms are distributed over a large series of Drigalski-Conradi plates."

"(*c*) Examine another liter by the caffeine method."

" *All* suspicious colonies obtained from the three methods (and the total number may be large) are subcultivated into broth, and incubated at 37° C., until next day. They are all then examined in hanging drop, and those which show actively motile bacilli are tested with antityphoid serum. A fairly powerful serum should be available, and a dilution of not less than 1 per cent should be employed."

"All those which fail to show agglutination are rejected, while those reacting are each subcultivated into litmus-milk, glucose neutral-red broth, and lactose-peptone solution."

"All the organisms giving cultural characters in these media which accord with those of B. *typhosus* are fully worked out. The tests should include accurate and extended agglutination tests with highly dilute sera. Such organisms will usually be found to be very few in number."

APPENDIX IX.

PRESENT STATUS OF WATER ANALYSIS IN CONNECTION WITH THE INVESTIGATION OF TYPHOID EPIDEMICS.[1]

By Ernest C. Levy, M.D., Chief Health Officer, Richmond, Va.
(Formerly Director of Laboratory of City Water Department.)

THE frequency with which the writer receives inquiries from physicians in regard to examining water for typhoid bacilli is sufficient ground for believing that a brief paper dealing with the subject here chosen will have a certain amount of usefulness. Knowing that where a given water is responsible for an outbreak of typhoid fever the bacilli of this disease must have been present in the water, and having only rather general ideas of the methods of bacteriological examination of water, what more natural than that the average physician should consider the actual finding of typhoid bacilli as the natural and crucial test in these cases? It is the object of this paper to show why this direct method of solving the question is not applicable, and, furthermore, to point out briefly just what the water expert of to-day does in these cases, provided he can get his client to understand something of the matter — which end, in the writer's own experience, can always be accomplished by a plain statement of the facts in the case.

The first difficulty connected with placing the responsibility for an outbreak of typhoid fever by means of direct bacteriological examination for the detection of B. typhi, lies in the fact that, assuming the water to have been the actual cause, it is

[1] Reprint from *Virginia Medical Semi-Monthly,* Nov. 10, 1905.

impossible to get a sample of the right water for examination. The minimum period of incubation of typhoid fever is eight days, with an average period of two weeks. Hence, assuming a water-supply to become infected, it is not until two weeks later that a sufficient number of cases of the disease have developed to attract considerable attention, and allowing (a liberal estimate) a week more for the physician or health officer to reflect on the subject and get into communication with the bacteriologist, it is three weeks altogether before the investigation is started. It is self-evident that, unless the pollution is a continuous one (which is not usually the case) the failure to find typhoid bacilli at this late date cannot be taken as indicating that the water was not originally infected and gave rise to the outbreak.

Coming now to the question of the actual examination of water for B. typhi, it is not at all difficult to explain why our methods are so imperfect. In almost every instance where a stream becomes infected by typhoid bacilli this stream receives at all times the fecal dejecta of a number of persons, and it is only when one of these individuals develops typhoid fever that the bacilli of this disease are added to the water, along with the continued discharges of a number of unaffected persons. Now, even the dejecta of the typhoid patient himself contain B. coli (the normal inhabitant of the intestinal canal) in probably greater numbers than B. typhi, while still larger numbers of the former organism continue to enter the stream in the stools of the healthy inhabitants of the watershed. We must, therefore, realize that almost invariably a water which has become infected with B. typhi has, along with these organisms, an immensely larger number of B. coli, the only exception to this being where a water has become infected by the urine of a typhoid patient but is otherwise unpolluted — obviously a most unusual condition. Besides this, a water so polluted as the one we are considering in our typical case is certain to contain large numbers of bacteria of other kinds, so that for every typhoid bacillus present there are probably an immense number of bacteria of other varieties.

Let us assume a concrete illustration for the sake of making clearer the problem which confronts the bacteriologist in these cases. A water would surely be seriously infected if each glassful contained 20 typhoid bacilli, yet, since an ordinary drinking glass holds about 200 cubic centimeters, in this case there would be only a single typhoid bacillus in each 10 cubic centimeters of the water. Such a water would almost certainly contain at least 200 bacteria of other kinds per cubic centimeters or 2000 in the 10 cubic centimeters. In our hypothetical case, therefore, for each typhoid bacillus there would be 2000 other bacteria.

Under such conditions let us see what would be the chance of finding typhoid bacilli. In the routine method of plating on gelatine, it would be necessary to make ten plates of one cubic centimeter each in order to get a single colony of B. typhi (assuming the typhoid bacilli to be evenly distributed through the water), and after all the colonies have developed there are no characteristics by which a typhoid colony can be picked out on sight, while it is obviously impossible to make the necessary detailed study of so large a number of colonies as would be necessary to identify the typhoid colony from others resembling it. If instead of gelatine we use agar and incubate at 37° C., a smaller number of total colonies will develop, but even here it would be impossible to tell if one of these was B. typhi, except by a most tedious and practically impossible detailed study of hundreds of colonies.

Evidently, then, simple plating is not to be considered as a means of detecting typhoid bacilli in water, and we are brought to look into whether there can be found some differential method which will allow the typhoid bacilli, if present, to develop, while restraining the numerous other forms which must always be conceived as being present. Many methods of this sort have been suggested from time to time, but not one of them is to be relied on, the chief difficulty being that the colon bacillus, always present, is much hardier than the typhoid bacillus, and no means are yet known of inhibiting the growth of the former and still permitting the latter to proliferate. It must be made clear that there is no difficulty in differentiating B. coli from B. typhi when cultures of each are at hand, but the problem is to obtain the latter at all in the presence of large numbers of the former and large numbers of bacteria of still other kinds.

Recognizing that one of our difficulties is the fact that so large an amount of water must be examined to find even a single typhoid bacillus, it has been recommended to pass a considerable amount of water through a porcelain filter and take for examination some of the scrapings from the filter, which will then contain, in small bulk, all the bacteria originally present in the water. As a matter of fact this in no wise lessens our troubles, for we now have an enormously increased number of B. coli and other bacteria to deal with, and this, as pointed out above, is our greatest difficulty after all.

If, following any of the very doubtful methods which have been proposed, the bacteriologist at last secures what he suspects may be a culture of B. typhi, the further task of making certain of this point is by no means an easy one. B. typhi is distinguished largely by negative characteristics, both morphological and cultural, nor is it pathogenic in a true sense for any of our laboratory animals. Even the serum reaction, lauded as specific when first brought, has come to be recognized as a test demanding the utmost care in technique and in interpretation.

Owing, then, to the difficulties above hastily outlined, an experienced man in this branch of sanitary science will not undertake to examine a water at all for B. typhi, or at any rate he will stake nothing on the result. But, while the problem cannot be solved in this direct manner, still it is possible in nearly every instance to arrive at results in a different way, and this true method of approach is, after all, of far greater value than a mere finding or not finding of typhoid bacilli in the water could possibly be.

The correct way of solving the problem, as matters stand, is to make a thorough study of each specific case which arises, along well recognized lines. Briefly, this includes a sanitary survey of the watershed, a study of the epidemic itself, and a bacteriological and chemical examination of the water. The sanitary survey is to be regarded as an indispensable factor in every case of importance, and as such it cannot be entrusted to anyone who has not had special training in just this kind of work. Each case presents its own peculiarities, and some point which it is impossible to foresee may give the clue to the whole situation.

Along with this sanitary survey, inquiry should be made into the special features of the epidemic itself. To do this thoroughly is the work of weeks, or even months in the case of large communities and extensive epidemics, but sufficient information for practical purposes may frequently be gained in a few hours of intelligent study in smaller communities, especially if the local physicians' records are fairly complete.

This visit to the seat of the trouble, moreover, enables us to judge of just what samples we wish to have for analysis and to collect these under the best conditions and with proper precautions. It also enables us to start certain parts of the bacteriological work on the spot, which is a matter of no little moment if at some distance from the laboratory. The tests which will be applied are, in a broad sense, for the determination of fecal pollution in general. Both chemistry and bacteriology are called upon, but the chief thing is the detection of intestinal bacteria.

After getting together all the facts both of the analysis and of the sanitary survey and special study, a careful consideration of all the data thus available will, in almost every instance, lead to a thoroughly trustworthy opinion. It is just at this part of the work that judgment and experience come most into play. The data at hand are to an expert in this line what the previous history, symptoms and physical signs are to the physician in arriving at a diagnosis, and each reaches his final opinion by a careful weighing of all the evidence and not by blind reliance upon any isolated fact.

This simile may be carried further. Certain cases of disease may be diagnosticated by a laboratory test of material secured from the patient, as, for instance, is possible by a sputum examination in cases of pulmonary tuberculosis, but no physician would care to take the responsibility of treating a case of consumption merely on the evidence thus afforded, without examining the patient and learning a great deal about his general condition and his environment. Just so, the water expert may often be able to decide by analytical methods whether or not the water is polluted, but knowledge so gained is always of a general character, and personal study of the case on the ground is necessary for the correction of existing conditions.

We may apply our simile, furthermore, to negative cases. Where a sputum examination does not show tubercle bacilli, but where the patient is nevertheless seriously ill, the examination will show little of what the real condition is. So with water, finding that, so far as a mere laboratory examination can ever show, the water is all right, but if, in spite of this, typhoid fever has been very prevalent, our examination is of value merely by the probable elimination of the water as a cause, but it has thrown no light whatever on what is responsible for the trouble. And, again, our work would be incomplete and misleading where the water was only one of several causes. By means of a personal survey, if the water was found not responsible, or responsible only in part, the search would be continued to arrive at every factor in the case.

The main points may be briefly summed up as follows:

(1) No satisfactory method is known for the detection of B. typhi in water.

(2) Were such a method known, it would be of limited application on account of the fact that when an outbreak of typhoid fever leads to an investigation, the water supposed to have been infected is no longer available for examination.

(3) Although the direct detection of B. typhi in water is impossible, yet the importance of bacteriological and chemical examination of the suspected water must not be underestimated, but it should be combined with a thorough sanitary survey of the field, and a competent study of the phases of the epidemic. This will almost invariably solve the question whether the outbreak was caused by drinking-water.

(4) This method of attacking the problem has the further advantage of throwing light on the sanitary quality of the water in question apart from the special outbreak of typhoid fever, and, moreover, if it is found that the water is not responsible, or responsible only in part, full information will be gained along many lines, thereby suggesting the steps to be taken for future protection.

APPENDIX X.

THE VIABILITY OF THE TYPHOID BACILLUS UNDER NATURAL CONDITIONS.[1]

By Herbert D. Pease, M.D., Director New York State Hygienic Laboratory, Albany, N.Y.

SIMPLE of solution as this subject may appear to be to the uninitiated, it is in reality one which has occupied the attention of bacteriologists and engineers for many years. However, upon certain aspects of the subject much has apparently been accomplished in the last five years.

That the subject is of importance is quite evident to those who have followed the results of the studies of outbreaks of typhoid fever published during the last half decade. Such studies are demonstrating more and more that epidemics of the disease are caused by unusual combinations of natural and artificial conditions which cannot be foreseen or foretold, and which can only be prevented by directing special attention in two directions — first, toward the great public improvements in water purification, sewage disposal and milk production and distribution; and, secondly, toward the proper hygienic management of each case of the disease.

This review will not attempt to consider the latter aspect of the subject in which the relation of the typhoid bacillus to the infected patient would naturally come under discussion, but will deal with the fate of the typhoid bacillus as it passes from such a patient out into nature.

I will first discuss some of the available evidence as to the fate

[1] From *Medical Review of Reviews*, New York, September, 1907.

of the *bacillus typhosus* when deposited in various kinds of natural soils or earths.

Firth and Horrocks[1] reviewed the work done on this phase of the subject down to 1902, and concluded that the results were too contradictory and unsatisfactory to be accepted. They took to demonstrate the fate of *bacillus typhosus* in moist and dry soils of various kinds under natural conditions, such as the presence and absence of direct sunlight and the effect of washing of the soils by rains. Their results are of great interest and importance.

They found that the typhoid bacillus had a long life, of at least two months, in the various soils when the same were kept moist; that they showed no tendency to multiply in such soils or to grow in any direction; that they could be washed by water for at least 18 inches through fine, closely packed earth without cracks or fissures; that the presence or absence of organic matter or sewage in the soil did not materially affect its existence, either favorably or otherwise; that when any of the kinds of typhoid-contaminated soils or earths were allowed to dry so as to form dust, the typhoid bacillus could be found living in it after 25 days, and that the dust blown from such dirt contained living typhoid bacilli.

They likewise found that 122 hours of direct sunlight during 21 days was not sufficient to kill the typhoid bacillus present in soils. They also ascertained that the freezing of soil containing typhoid bacilli for periods of several days did not completely kill these bacteria.

In none of the experiments made by these authors were attempts made to determine quantitative viability as well as qualitative, and they are open to this objection.

Rullmann[2] found that the typhoid bacillus lived for at least a year and a half in otherwise sterile earth and gravel, but in that time had died out in sand. The numbers were greatly reduced,

[1] Firth and Horrocks: *British Medical Journal*, 1902, Vol. 92, p. 936.

[2] Rullmann: *Centralblatt fur Bakteriologie*, Erst Abt.; Originale, XXXVIII, p. 380.

however, in all, and the reduction was greater in the earth than in the gravel.

Levy and Keyser[1] claim to have found living typhoid bacilli in clayey garden soil, which had been manured with the contents of a water-tight privy into which typhoid-infected stools had been deposited five months previously.

From the results of these investigators, it would appear that all forms of moist human excrement, dirt, soil, sand, or gravel favor the viability of the typhoid bacillus, while even the same materials in a dry state support its existence for a considerable period, often over a month. It would also appear that freezing and direct sunlight have but little effect upon the typhoid bacillus in soils, and that they can be washed for a considerable distance through well-packed earth and retain life.

These conclusions of laboratory investigations are in entire harmony with the known facts concerning the origin of numerous epidemics of typhoid fever. In many of these cases it has been shown that typhoid discharges thrown upon the surface of the ground, or buried superficially during the winter, and which have remained in these locations for several months, undergoing freezing and more or less exposure to sunlight, have finally been carried into waters for potable purposes and have produced widespread epidemics. The New Haven, Conn., epidemic of 1901 was brought about in this way. Many other instances of a similar kind could be quoted.

When we come to the consideration of the experiments on the viability of the typhoid bacillus in water and sewage, the results are found to be somewhat different.

In water the typhoid bacillus is subject to conditions and agencies of a physical, chemical or biological character. The physical agencies, such as gravity, sunlight and temperature, probably play a most important part in rendering water an unfavorable soil for the existence of the typhoid bacillus, but chemical agencies, such as the presence of metals or inorganic compounds, absence

[1] Levy and Kayser: *Centralblatt fur Bakteriologie*, Erste Abt.; Orig., XXXIII, 489.

of oxygen and usual organic matter, likewise play a considerable rôle in this direction under certain circumstances, while the biological agencies, such as the indirect or direct antagonism of other bacteria and of protozoa, likewise aid materially in the destruction of these pathogenic bacteria.

One of the most potent factors in the elimination of typhoid bacilli from water is sedimentation. The effect of this agency is so well known and consistently recognized that it is not necessary to dwell upon it at length. Sedimentation was the agency to which Jordan [1] attributed a large part of the purification of the Chicago Drainage Canal and the Illinois river. This force, of course, acts in inverse proportion to the amount of current or motion in a body of water. Bissell [2] has stated that he found as many colon bacilli in the waters of Niagara River below Niagara Falls as above it. The fate of the typhoid bacillus after it has reached the bottom of a body of water has not been studied to any great extent. The solution of the problem has not great practical importance except in connection with the matter of the pollution of edible shellfish, such as oysters and clams.

Savage [3] studied the effect of what he calls tidal mud upon the typhoid bacillus, and found that the latter can survive fairly readily for two weeks in tidal mud, but after this period their numbers rapidly diminish. He believes that the examinations of mud when obtainable form a better index of the pollution of a stream or other body of water than the examination of the water itself.

That direct sunlight, and even diffuse daylight, had a marked destructive effect on typhoid bacilli, as well as other bacteria in water, has been well recognized since the early work of Buchner.[4] He concluded that direct sunlight is a more potent factor in redu-

[1] Jordan: *Journal of Experimental Medicine*, 1900, V, 271.

[2] Bissell: Proceedings American Public Health Association, 1903, XXIX, 360.

[3] Savage: *Journal of Hygiene*, 1905, Vol. 5, p. 146.

[4] Buchner: *Centralblatt fur Bakteriologie*, XI, 781. Quoted by Wheeler: *Journal of Medical Research*, 1906, XV, 277.

cing the number of bacteria in natural bodies of water than sedimentation.

Procacci exposed water in deep cylinders to the nearly vertical rays of the sun, and found that after three hours the water in the cylinders was sterile to the depth of one foot, while at a depth of two feet the typhoid bacilli were unaffected.

Clark and Gage[1] found that typhoid bacilli in a thin layer of water were destroyed by the direct sunlight in one hour, and that when they were exposed in bottles of water their extinction was accomplished in five hours.

Wheeler[2] has shown that diffuse daylight has a detrimental action on *bacillus typhosus* in waters contained in glass bottles.

Weinzirl[3] has recently shown that direct sunlight has an even more powerful germicidal action than has been shown by previous experimenters. The defects in former methods of testing were caused by the deflection, reflection and absorption of the sun's rays by the glass vessels, etc., used to maintain the specimens free from contamination by foreign bacteria.

While sunlight unquestionably has a very destructive effect upon typhoid bacilli in water under most natural conditions, its failure to seriously affect these bacteria when the latter were placed in earth and dirt, as shown by the Firth and Horrock's tests, already referred to, indicates that there must be some other condition than the mere presence of the sunlight which gives material aid to its disinfecting action when the bacilli are in water. This will be again referred to when the effects of the presence and absence of dissolved oxygen in the water is taken up for consideration.

The effects of different degrees of temperature on typhoid bacilli in water is most interesting. As is well known, the optimum temperature for their growth in culture media is that of the human body.

[1] Clark and Gage: Annual Report Massachusetts State Board of Health, 1902, 275.

[2] Wheeler: *Journal of Medical Research*, 1906, XV, 269.

[3] Weinzirl: *Journal Infectious Diseases.* Supplement III, May, 1907.

Clark and Gage[1] found that when in water it could resist a temperature of 80° C. for five minutes. However, they found that the optimum temperature for the viability of the bacillus in water was 20–22° C., or the so-called room temperature, and that 37° C., or the body temperature, exerted a detrimental effect. This has been confirmed by Conradi and Bolton[2] and by Wheeler,[3] who, in addition, has shown that the room temperature is more favorable to typhoid bacilli in water than is that of the refrigerator. He also states that temperatures approximating 0° C., and 32° F., are decidedly detrimental to these bacteria in at least three classes of water.

Smith and Swingle[4] state that the critical temperature for the life of bacteria is about 0° C.

One of the first tests of the effect of actual freezing upon *bacillus typhosus* was made by Prudden[5] in 1887. By the methods of testing which he used, namely, to freeze small amounts of water containing typhoid bacilli, he found that they lived in ice for 103 days.

Later Park[6] repeated these experiments, but made quantitative as well as qualitative tests, and determined that the decrease in the numbers of the typhoid bacilli was exceedingly rapid during the first few days or weeks. At the end of three weeks less than 1 per cent were alive.

Zeit[7] also repeated Prudden's experiment, and found that the typhoid bacilli were completely killed by freezing in 24 hours.

Clark and Gage[8] operated with much larger volumes of both water and sewage. They have shown that the typhoid bacillus

[1] Clark and Gage: Loc. Cit.

[2] Conradi and Bolton: *Centralblatt fur Bakteriologie*, Erste Abt.; Orig., XXXVI, 203.

[3] Wheeler: Loc. Cit.

[4] Smith and Swingle: *Science*, 1905, N. S., Vol. XXI, 481.

[5] Prudden: *Medical Record*, 1887, 31, p. 341.

[6] Park: *Journal Boston Society Medical Science.*

[7] Jordan, Russell and Zeit: *Journal of Infectious Diseases*, 1904, I, 660.

[8] Clark and Gage: Annual Report Massachusetts State Board of Health, 1902, 280.

is killed rapidly in both the freezing process and by low temperatures just short of freezing.

Many other experiments were made by them in which the typhoid bacillus was not introduced into the operations, bůt from the results of which conclusions as to the effect of freezing on the typhoid bacillus in water under natural conditions might with propriety be drawn.

Thus they found that from 95 to 99 per cent of all the water bacteria, and all of the colon bacilli in either water or sewage, were removed by freezing.

Samples of ice, and water under the ice, were taken by them from the polluted Merrimac River at points varying from three to eight and a half miles from the outlets from the sewers of a city of 90,000 inhabitants, and the ice had less than 0.3 per cent of the number of bacteria present in the water under it, and no colon bacilli were found in the ice.

Clark[1] believes that in the process of freezing, the bacteria, along with particles of dirt, substances in suspension and some of the mineral constituents of the water, are expelled into the underlying water. He thinks, therefore, that the physical condition of the water while freezing is of great importance, as this expulsion takes place most satisfactorily when the water is quiet.

Wheeler[2] obtained very similar results to those quoted in his laboratory tests of freezing typhoid bacilli in relatively small amounts of water. However, he does not consider Clark's explanation of the causation of the decrease in the numbers of bacteria in ice by expulsion as the correct one. He floated porcelain capsules containing some of the same typhoid-inoculated water as was in the pails they were floating in, and found that the typhoid bacilli were killed as completely and rapidly in the capsules as in the surrounding ice. He also obtained about as complete destruction of the typhoid bacilli in the underlying water in the pails as in the ice. However, his work was done on small

[1] Clark: Proceedings American Public Health Association, XXVII, 204.

[2] Wheeler: Loc. Cit.

volumes of water, previously sterilized by heat and laboratory conditions, while Clark's and Gage's work had been done under more natural conditions, in large volumes of water.

Wheeler obtained samples of ice and water from Lake Champlain at distances varying from 30 to several hundred feet from the sewer outlets of the city of Burlington. In the samples collected but 30 feet from the sewer outlets there were microscopic evidences of sewage. *Bacillus coli* was not found in any of the ice samples, but was present in large numbers in the underlying water.

Smith and Swingle[1] obtained a percentage destruction of over 91 in their laboratory freezing tests of the typhoid bacillus in bouillon. They believe, from freezing experiments done on other species of bacteria, that when a few organisms out of a culture show a special resistance to the freezing, that this resistance is due to absence of water in the protoplasm of those particular bacteria, and that they behave, therefore, like endospores, although the species may be one in which no endospores are to be found. Prudden, Park and others quoted found a small percentage of the typhoid bacilli in their cultures more resistant than the majority, and this endospore-like formation may be the explanation.

All the authors unite in the conclusion that repeated freezings and thawings are more destructive to typhoid bacilli than the single freezings.

There exists one reported instance in which not only was typhoid fever apparently transmitted to well persons by means of ice, but in which the investigators believed that they isolated typhoid bacilli from the ice in question.

Hutchins and Wheeler[2] reported the occurrence of 39 cases of typhoid fever in the St. Lawrence State Hospital at Ogdensburg, N. Y., under conditions which led them to state with some degree of certainty that the disease was due to the use of ice taken from the St. Lawrence River.

[1] Smith and Swingle: Loc. Cit.

[2] Hutchins and Wheeler: *American Journal Medical Science*, 1903, Vol. 126, p. 680.

They examined clear ice taken from the river five months previously, which had been stored in one particular icehouse, the ice from which they had suspected as being the cause of the disease. In this ice were particles of dirt, and from these they isolated in pure culture several colon bacilli, and one which they considered *bacillus typhosus*.

If Clark's theory concerning the elimination of particles of dirt, etc., from still water as it freezes is correct, and it is generally accepted, then this ice must have been formed when the water was in active motion, or the ice was flooded with the infected water and opportunities for the exclusion of the dirt prevented, or under some other very unusual condition.

Ice had been cut from this location for the twelve years prior to the outbreak, and no typhoid fever traceable to it had been observed. It is of special significance that all the ice suspected of causing the disease came from one particular icehouse, although all were filled with ice from the same general location. The conclusion would seem to be irresistible that the pollution of this ice came about in some very special manner, the true nature of which the authors were unable to determine.

Hill,[1] in a report on the ice supply of the city of Boston, remarks that the purification of polluted water, which takes place during the process of freezing and including the subsequent three weeks, is equivalent to the filtration of that water by the most efficient slow sand filters: This opinion is in harmony with those expressed by Sedgwick[2] and others.

But little is known of the effect, if any, of the natural mineral constituents of water upon the typhoid bacillus, and it is not intended to here discuss the subject of the effect of the artificial addition of inorganic elements or compounds, such as copper sulphate, for the destruction of bacteria.

The oxygen content of a given water containing typhoid bacilli is undoubtedly a factor of the greatest importance in relation to

[1] Hill: *Boston Medical and Surgical Journal*, 1901, CXLV, 557.

[2] Sedgwick: "Sanitary Science," 1905.

the viability of these organisms, but it has as yet received but little attention.

Whipple and Mayer[1] have, however, clearly shown that the absence of dissolved oxygen has a most decided and rapid detrimental effect upon typhoid bacilli in both water and bouillon. They question whether this fact has been given the consideration which it deserves in the interpretation of the results of laboratory experiments upon the viability of this organism. Experiments in which small amounts of water, sewage or bouillon, sterilized by heat, are utilized should certainly take into consideration the question of the lack of oxygen in such liquids. The difference in resistance of the typhoid bacillus in soils and in liquids under apparently similar physical conditions, as already noted, may possibly be due to a greater amount of oxygen in the soils than in the liquids.

This conception of Whipple and Mayer is of the greatest importance, as it involves the question of the effect of the almost total lack of oxygen in the effluent of septic tanks upon the typhoid bacilli which are present in most raw sewages. If typhoid bacilli cannot exist for more than one or two days in the septic tank it is a fact of the utmost importance.

The relation between the presence of organic matter in water and the viability of the typhoid bacillus is likewise an important matter.

In the early days of bacteriology Bolton showed that in water repeatedly redistilled and inoculated with typhoid bacilli, so as to avoid introducing organic matter, the typhoid organisms died out rapidly.

Wheeler[2] also shows that the less organic matter present in water the less favorable the influence upon the viability of the typhoid bacillus.

By far the most extensive and valuable series of tests made upon this phase of the subject were those of Jordan, Russell and

[1] Whipple and Mayer: *Journal of Infectious Diseases*, 1906, Supplement II, p. 76.

[2] Wheeler: Loc. Cit.

Zeit,[1] and later of Russell and Fuller.[2] They tested the effect of natural conditions, excluding sunlight, upon celloidin, agar or parchment capsules, to which typhoid bacilli placed in various relatively unpolluted and polluted waters and sewage were likewise added, and in which also the capsules were then floated.

All possible grades and combinations from relatively pure waters to sewage inside these permeable sacs to sewage and relatively pure waters outside of them, and varying conditions from those done in nature to those in the laboratory were utilized in these tests.

The authors conclude that in relatively pure waters, of a surface character, the typhoid bacillus is capable of retaining its vitality for about eight days.

When the typhoid bacillus was inoculated into sewage it completely disappeared in five days, and even in two or three days the majority of the organisms were killed off. They believe, therefore, that the typhoid organism in natural sewage does not live as long as it will in relatively pure water.

They believe that the activity of the saprophytic bacteria in the sewage and polluted water plays a considerable rôle in this rapid destruction of the typhoid organism. However, the most convincing work on this aspect of the subject has been done by Frost,[3] working with a similar technique of celloidin sac containing typhoid-inoculated fluids, with growths of saprophytic bacteria in the water, and bouillon in which the sacs are placed.

The saprophytic bacteria he used were obtained from garden earth, street dust, sand and various waters. In many tests the soils themselves were inoculated into liquid surrounding the sacs.

Frost found that the typhoid bacilli were rapidly killed in these sacs by thermostabile products of the growth of certain soil bacteria (B. vulgatus, B. vulgaris, Pa. fluorescens and Pa. putida), which acted best at body temperature, but which were appar-

[1] Jordan, Russell and Zeit: Loc. Cit.

[2] Russell and Fuller: *Journal of Infectious Diseases*, 1906, Supplement II, p. 40.

[3] Frost: *Journal of Infectious Diseases*, 1904, I, 599.

ently uninfluenced by other conditions. They operate, however, only when these bacteria are grown with or slightly in advance of the typhoid bacillus. These thermostabile substances undoubtedly, therefore, play directly a large part in the destruction of typhoid bacilli in water and sewage under natural conditions.

Frost was unable to explain their very feeble action at low temperatures; nor is there any explanation as yet offered as to why they do not act more promptly on typhoid bacilli in soils. It may be possible that they operate more strongly in the absence of oxygen. Frost was not specially clear on this point.

Wheeler[1] found a harmless saprophytic *bacillus carrotoverus* which actually stimulated the development of the typhoid bacillus when sown with it.

Huntemüller[2] has shown that various low forms of protozoa are capable of feeding upon typhoid bacilli.

Klein[3] has shown that normal oysters, clams and other shellfish, when grown in unpolluted waters, do not contain bacillus coli or sewage bacteria in their intestinal canals, but that when placed in sewage-polluted waters they become badly contaminated by such organisms. However, if they are removed from such polluted waters and kept under favorable conditions, they have the power of freeing themselves from both these colon and typhoid bacilli previously taken in. The rate at which this is accomplished depends upon the severity of the pollution.

[1] Wheeler: Loc. Cit.

[2] Huntemüller: *Archiv fur Hygiene*, 1905, LIV, 89.

[3] Klein: *Lancet*, 1905, Vol. 168, p. 1133.

APPENDIX XI.

TYPHOID FEVER IN UNITED STATES ARMY CAMPS.

(*From the Report on the Origin and Spread of Typhoid Fever in the United States Military Camps during the Spanish War of* 1898, *by Dr. Walter Reed, Dr. Victor C. Vaughan and Dr. Edward O. Shakespeare.*)

General Statements and Conclusions.

1. During the Spanish War of 1898 every regiment constituting the First, Second, Third, Fourth, Fifth and Seventh Army Corps developed typhoid fever.

2. More than 90 per cent of the volunteer regiments developed typhoid fever within eight weeks after going into camp.

3. Typhoid fever developed also in certain of the regular regiments within three to five weeks after going into camp.

4. Typhoid fever became epidemic both in the small encampments of not more than one regiment, and in the larger ones consisting of one or more corps.

5. Typhoid fever became epidemic in camps located in the Northern as well as in those located in the Southern States.

6. Typhoid fever is so widely distributed in this country that one or more cases are likely to appear in any regiment within eight weeks after assembly.

7. Typhoid fever usually appears in military expeditions within eight weeks after assembly.

8. The miasmatic theory of the origin of typhoid fever is not supported by our investigations.

9. The pythogenic theory of the origin of typhoid fever is not supported by our investigations.

10. Our investigations confirm the doctrine of the specific origin of typhoid fever.

11. With typhoid fever as widely disseminated as it is in this country, the chances are that if a regiment of 1300 men should be assembled in any section and kept in a camp the sanitary conditions of which were perfect, one or more cases of typhoid fever would develop.

12. Typhoid fever is disseminated by the transference of the excretions of an infected individual to the alimentary canals of others.

13. Typhoid fever is more likely to become epidemic in camps than in civil life because of the greater difficulty of disposing of the excretions from the human body.

14. A man infected with typhoid fever may scatter the infection in every latrine in a regiment before the disease is recognized in himself.

15. Camp pollution was the greatest sin committed by the troops in 1898.

16. Some commands were unwisely located.

17. In some instances the space allotted the regiments was inadequate.

18. Many commands were allowed to remain on one site too long.

19. Requests for change in location made by medical officers were not always granted.

20. Superior line officers can not be held blameless for the unsanitary condition of the camps.

21. Greater authority should be given medical officers in questions relating to the hygiene of camps.

22. It may be stated in a general way that the number of cases of typhoid fever in the different camps varied with the methods of disposing of the excretions.

23. The tub system of disposal of fecal matter as practiced in the Second Division of the Seventh Army Corps is to be condemned.

24. The regulation pit system is not a satisfactory method of disposing of fecal matter in permanent camps.

25. In permanent camps, where water carriage cannot be secured, all fecal matter should be disinfected and then carted away from the camp.

26. Infected water was not an important factor in the spread of typhoid fever in the national encampments in 1898.

27. To guard against the contamination of the water supply, troops in the field should be provided with means for the sterilization of water.

28. Flies undoubtedly served as carriers of the infection.

29. It is more than likely that men transported infected material on their persons or in their clothing and thus disseminated the disease.

30. Typhoid fever, as it developed in the regimental organizations, was characterized by a series of company epidemics, each one having more or less perfectly its own individual characteristics.

31. It is probable that the infection was disseminated to some extent through the air in the form of dust.

32. A command badly infected with typhoid fever does not lose the infection by simply changing location.

33. When a command badly infected with typhoid fever changes its location it carries the specific agent of the disease in the bodies of the men, in their clothing, bedding, and tentage.

34. Even an ocean voyage does not relieve an infected command of its infection.

35. After a command becomes badly infected with typhoid fever, changes of location, together with thorough disinfection of all clothing, bedding, and tentage is necessary.

36. Except in case of the most urgent military necessity one command should not be located upon the site recently vacated by another.

37. The fact that a command expects to change its location does not justify neglect of proper policing of the ground occupied.

38. It is desirable that the soldier's bed should be raised from the ground.

39. In some of the encampments the tents were too much crowded.

40. Medical officers should insist that soldiers remove their outer clothing at night when the exigencies of the situation permit.

41. Malaria was not a prevalent disease among the troops that remained in the United States.

42. The continued fever that prevailed among the soldiers in this country in 1898 was typhoid fever.

43. In addition to the recognized cases of typhoid fever, there

were many short or abortive attacks of this disease which were generally diagnosed as some form of malarial fever.

44. While our examinations show that coincident infection with malaria and typhoid fever may occur, the resulting complex of symptoms are not sufficiently well defined and uniform to be recognized as a separate disease.

45. About one-fifth of the soldiers in the national encampments in the United States in 1898 developed typhoid fever.

46. Army surgeons correctly diagnosed about half the cases of typhoid fever.

47. The percentage of death among cases of typhoid fever was 7.61.

48. When a command is thoroughly saturated with typhoid fever it is probable that one-fourth to one-third of the men will be found susceptible to this disease.

49. In military practice typhoid fever is often apparently an intermittent disease.

50. The belief that errors in diet with consequent gastric and intestinal catarrh induce typhoid fever is not supported by our investigation.

51. The belief that simple gastro-intestinal disturbances predispose to typhoid fever is not supported by our investigation.

52. In a considerable per cent (a little more than one-third) of the cases of typhoid fever which are recorded as having been preceded by some intestinal disturbance, the preceding illness was so closely followed by typhoid fever that we must regard the former as having occurred within the period of incubation of the latter.

53. More than 90 per cent of the men who developed typhoid fever had no preceding intestinal disorder.

54. The deaths from typhoid fever were 86.24 per cent of the total deaths.

55. The morbidity from typhoid fever per 1000 of mean strength was a little less than one-fifth (192.65).

56. The mortality from typhoid fever per 1000 of mean strength was 14.63.

57. The average period of incubation in typhoid fever is probably about ten and a half days.

The following table contains data illustrating these points:

Command, etc.	Number of Regiments.	Mean Strength.	Cases of Typhoid Fever, Certain and Probable.	Deaths from Typhoid Fever.	Death Rate per 100,000.	Morbidity Rate per 100,000.	Percentage of Fatality, Certain and Probable Type.	Deaths from all Diseases.	Percentage of Deaths from Typhoid to Deaths from all Diseases.
First Army Corps (Chickamauga)	22	27,380	5,921	344	1,219	21,625	5.64	397	84.13
Third Army Corps (Chickamauga)	17	20,568	4,418	417	2,027	21,479	9.43	469	88.9
Fourth Army Corps (Tampa) . .	7	7,507	1,498	99	1,317	19,954	6.60	112	88.39
Second Army Corps (Alger) . . .	18	19,807	2,226	212	1,070	11,238	9.52	259	81.87
Second Army Corps (Meade) . .	22	13,962	2,690	150	1,074	19,267	5.57	168	89.28
Seventh Army Corps, Second Division (Jacksonville)	9	10,759	2,693	248	2,305	25,030	9.20	281	88.25
Total	85	99,983	19,446	1,460	1,460	19,449	7.50	1,686	86.59
Seventh Army Corps, Third Division	7	7,990	1,292	120	1,501	16,170	9.28	146	82.19
Grand Total	92	107,973	20,738	1,580	1,463	19,265	7.60	1,832	86.24

APPENDIX XII.

EXTRACT FROM THE PRESIDENTIAL MESSAGE OF THEODORE ROOSEVELT, DECEMBER, 1907.

Larger Medical Corps Needed.

The Medical Corps should be much larger than the needs of our Regular Army in war. Yet at present it is smaller than the needs of the service demand even in peace. The Spanish War occurred less than ten years ago. The chief loss we suffered in it was by disease among the regiments which never left the country. At the moment the nation seemed deeply impressed by this fact; yet seemingly it has already been forgotten, for not the slightest effort has been made to prepare a medical corps of sufficient size to prevent the repetition of the same disaster on a much larger scale if we should ever be engaged in a serious conflict.

The trouble in the Spanish War was not with the then existing officials of the War Department; it was with the representatives of the people as a whole who, for the preceding thirty years, had declined to make the necessary provision for the army. Unless ample provision is now made by Congress to put the Medical Corps where it should be put, disaster in the next war is inevitable, and the responsibility will not lie with those then in charge of the War Department, but with those who now decline to make the necessary provision. A well-organized medical corps, thoroughly trained before the advent of war in all the important administrative duties of a military sanitary corps, is essential to the efficiency of any large army, and especially of a large volunteer army.

Such knowledge of medicine and surgery as is possessed by the medical profession generally will not alone suffice to make an efficient military surgeon. He must have, in addition, knowledge of the administration and sanitation of large field hospitals and camps, in order to safeguard the health and lives of men intrusted in great numbers to his care. A bill has long been pending before the Congress for the reorganization of the Medical Corps; its passage is urgently needed.

APPENDIX XIII.

MEDICINE IN PEACE AND WAR.

By Dr. Louis Livingston Seaman, New York.

(*From the New York Medical Journal, February 22*, 1908.)

The splendid achievements of scientific medicine in civil life in the prevention of disease should be even more effectually obtained in the army, where only healthy men are accepted, and vigorous outdoor camp life should keep its units, who are subject to strict military discipline, in perfect physical condition. Health alone, however, is no guarantee against the insidious attack of the silent foe that lingers in every camp and bivouac. It is this foe, as the records of wars for the past 200 years have proved, that is responsible for four times as many deaths as the guns of the enemy, to say nothing of the vast number temporarily invalided or discharged as unfit for duty. It is this dreadful unnecessary sacrifice of life from preventable disease that constitutes the hell of war.

* * * * * * *

Unless an army maintains a thoroughly organized sanitary corps, prepared to fight germs and diseases in advance of the fighting forces, testing the water supplies, and avoiding the dangers from contagion and infection, the medical department might as well be abolished. If the Japanese had not realized this before their last war and taken measures to prevent disease, their army would never have won their brilliant and uninterrupted series of victories. If they had sustained the same ratio of mortality from sickness as in their war with China ten years before, their losses from disease alone in the

Russian war would have nearly equaled the total of their entire losses from all causes. This proves the value of the medical and sanitary corps, and illustrates its importance as a factor in the winning of the final issue.

The days of operative surgery on the field of battle or at the front passed with the discovery of asepsis and antisepsis. The Russo-Japanese war taught many lessons and destroyed many ideals in matters military as in matters surgical, where the hitherto accepted idea of the duties of the military surgeon was shown to be erroneous, where asepsis and antisepsis relegated the use of the scalpel to comparative obscurity and demonstrated conclusively that preservation of the army by prevention of disease is the surgeon's duty, first, last, and nearly all the time. In surgical technique, or in the after treatment of the wounded and sick, the Japanese taught the foreigner comparatively little, but in the field of sanitary science and dietetics they demonstrated what had never been done before, viz., that preventable diseases *are* preventable and can be controlled; and that the great incubus of an army in the field, the presence of crowded hospitals and the large and expensive force necessary to equip and conduct them, can to a large extent be eliminated.

* * * * * * *

The Medical Department of our army, whose archaic system almost parallels that of Peking, while falling far below that of Patagonia (and I am familiar with both and speak advisedly), although unequal to cope with the exigencies of the Spanish campaign, is to-day, as the Surgeon General states, relatively 50 per cent worse off in numbers than at the close of the Civil War in 1864, or at the termination of the Spanish-American campaign. *The theory upon which it is founded that the cure of disease rather than its prevention is its objective, still remains in vogue.* Although men of brilliant attainments and individual merit are found on its staff, the deplorable system under which they are compelled to serve, and their lack of authority to enforce sanitation and hygiene, render the advisability of the continuance of the department under present conditions problematical.

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Under the present system, the same old medical regulations remain in vogue to all intents and purposes as prevailed before the microbic origin of disease was discovered and the key to sanitation found. So that, if another war were to be declared next summer, our government would again convert the units of its army into hospital patients, and its veterans into pensioners.

* * * * * * *

Under the present system the line officer of the army is under no obligation to accept the recommendation of the medical officer as to the site or sanitation of a camp. Even in time of peace, he has no executive power to enforce sanitation, although he may be convinced that the health of every man is being jeopardized.

* * * * * * *

The officers of artillery, of cavalry, of infantry, the engineers, and of the signal service, can compel obedience to their orders, but the medical man, whose department fights the foe that has killed 80 per cent in the majority of the great wars of history, cannot enforce an order, but can only make a recommendation, which the line officer can accept or reject at his discretion.

* * * * * * *

The importance of the medical, as compared with the other staff departments, has never been recognized or appreciated. Until it is realized that the most important function of the medical officer is in the prevention of disease rather than its cure, the old custom will prevail. To be efficient the medical officer must not only be a good physician, but a sanitarian, a bacteriologist, often a chemist as well as an administrator. Upon him devolves the duty of preventing disease, and his part in maintaining the effectiveness of the units makes him an important factor in the military establishment. His status is essentially military, not in the sense of holding command, but as an integral part of an organization, complex in its composition, and whose different members should be so organized as to produce a harmonious and effective whole. Under the existing system, he is looked upon simply as a doctor, whose sole function is treating the sick and wounded — whose duties should be confined to the hospital, and whose recommendations should be submitted only when asked for.

* * * * * * *

The entire appropriation of the Medical Department for the fiscal year of 1898 was less than $1,000,000; this was increased at the outbreak of hostilities with Spain by something over $2,000,000. Then came the war. As a result of that almost bloodless conflict, the actual hostilities of which lasted only less than six weeks, we paid last year alone $3,471,157 in pensions, with the further assurance of an annual increase for many years to come. The rolls of the Pension Office to-day bear the names of 24,000 pensioners, over 19,000 of whom are invalids and survivors of this war, and over 18,000 additional claims are now pending; although the total of the Cuban army of invasion was only 20,000 men.

* * * * * * *

Let us hope that the day is not distant when the true value of the medical man in war will be appreciated in our own land and he will be given the authority in his own sphere that will make it possible for our army in the day of emergency to equal, if not surpass, this splendid record. Braver men never served with the colors than the American soldiers, as we proved on both sides of the Civil War, where many battles (in one of which, at Cold Harbor, ten thousand men fell in ten minutes) exceeding anything known in the Orient, and where it was conclusively proved that our soldier deserves every care and protection a generous government can bestow.

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APPENDIX XIV.

DATA AS TO COST OF TYPHOID FEVER.

THE following data are taken from the *Engineering News*, of March 5, 1908, in which quotations are given from a report by Mr. Frank E. Wing, Associate Director of the *Pittsburg Survey*, being part of a sociological study carried on by the magazine " Charities and Commons of New York, by means of an appropriation from the Sage Foundation."

A study was made of the typhoid fever cases in Wards 8 and 11, of Pittsburg, Pa. Of the 433 cases that occurred in these wards during the year ending June 30, 1907, data were secured concerning 194. The data obtained are very instructive :

Number of families in which typhoid fever cases occurred....	149
Number of individuals in these families	999
Number of persons taken with typhoid fever during one year	194
Number of deaths from typhoid fever	11
Number of children taken with typhoid	89
Number of wage earners.............................	87
Number of weeks' work lost by these wage earners	964
Loss of wages..	$10,902
Loss of time by other wage earners caring for patients, weeks	182
Loss of wages by these caretakers.......................	$1,557
Number of cases treated in hospitals....................	53
Hospital costs paid by patients.........................	$1,141
Hospital costs paid by charity	$1,534
Doctors' and nurses' bills, medicines, etc., of patients treated at home	$8,179
Funeral expenses of six patients who died................	$1,032
Total cost...	$24,359
Fatality of the disease	5.7%
Cost of typhoid fever per patient	$125
Cost of typhoid fever per typhoid death..................	$2,200

APPENDIX XV.

TYPHOID FEVER LITERATURE.

THE literature of typhoid fever and its allied subjects is so enormous that to do it even scant justice would too greatly extend the limits of the present work, while any list of references that might be given as complete to-day would be incomplete to-morrow, so rapidly is the subject being developed. It is assumed therefore that those interested in the medical aspects of typhoid fever in its bacteriology, in water analysis and water filtration, in sewage purification, in milk pasteurization, and in the general engineering and sanitary matters involved in the prevention of the disease, will seek their information from the many published works on those topics.

For the benefit of students, however, a few references to reports and monographs descriptive of certain typhoid fever epidemics are given below. Descriptions of many other epidemics may be found in the files of the medical and engineering journals, in the annual reports of various state boards of health and the local boards of health of cities and towns and in the publications of the U. S. Governmental departments.

PARTIAL LIST OF REFERENCES TO TYPHOID FEVER OUTBREAKS AND EPIDEMICS.

City or Town and State.	Year of Occurrence.	Cause.	Investigator or Author.	Reference.
Albany, N. Y.		Water		Eng. News, Vol. 44, p. 88.
Augusta, Maine	1903	Water	Whipple and Levy	Jour. N. E. W. W. Asso., Vol. 19, p. 163, 1905.
Auxerre, France	1902	Water	Max le Couppey de la Forest	Revue d'Hygiene, Vol. XXIV, No. 6, 1902.
Baraboo, Wis.	1901	Water	Russel and Gorst	Wisconsin State Bd. of Health, Rept. 1901–2; also Eng. News, Vol. 47, p. 166.
Burlington, Vt.	1879–1905	Water	Baker	N. E. W. W. Asso., 1906, p. 163.
Do.		Water	Sedgwick	N. E. W. W. Asso.
Butler, Pa.	1903	Water	Soper	Eng. News, Vol. 50, p. 574.
Caterham, England	1879	Water	Sedgwick	Principles of Sanitary Science and the Public Health.
Chicago, Ill.		Water	Sedgwick and Hazen	Eng. News, Apr. 21, 1892.
Do.		Water	Jordan	Jour. Am. Med. Asso., Dec. 20, 1902.
Cleveland, Ohio	1903–4	Water	Whipple	N. E. W. W. Asso., 1906, p. 266.
Columbus, Ohio	1904	Water		Eng. News, Vol. 51.
Hudson Valley, N. Y.		Water	Mann	Albany Medical Annals, Apr., 1907.
Ithaca, N. Y.	1903	Water	Soper	Jour. N. E. Water Works Asso., Vol. 18, p. 431, 1904.
Lausen, Switzerland	1872	Water	Sedgwick	Principles of Sanitary Science and the Public Health.
Lawrence, Long Island, N. Y.	1905	Oysters	Soper	Medical News, N. Y., Feb. 11, 1905.

PARTIAL LIST OF REFERENCES TO TYPHOID FEVER OUTBREAKS AND EPIDEMICS—*Continued.*

City or Town and State.	Year of Occurrence.	Cause.	Investigator or Author.	Reference.
Lowell, Lawrence, Mass.	1890	Water	Sedgwick	Principles of Sanitary Science and the Public Health.
Lowell, Mass.	1903	Water		Eng. News, Vol. 50, p. 173.
Marlborough, Mass.	1894	Milk	Sedgwick	Principles of Sanitary Science and the Public Health.
Middletown, Conn.	1894	Oysters		An. Rept. Conn. St. Bd. of Health, 1895. Also Eng. News, Vol. 31, p. 479.
Montclair, N. J.	1894	Milk		Eng. News, Vol. 31, p. 324.
New Haven, Conn.	1901	Water	Smith	An. Rept. St. Bd. of Health, 1901.
Newark, N. J.	1898–9	Water	Herald	N. E. Water Works Asso., Vol. 25, p. 172.
Newport, R. I.	1900	Water	Winslow	Technology Quarterly, Vol. XIV, No. 2, June, 1901.
Paterson, N. J.		Water		Eng. News, Vol. 41, p. 160.
Philadelphia, Pa.		Water	Abbott	Eng. News, Vol. 51, p. 125, 130.
Pittsburg, Pa.		Water	Matson	Pittsburg Medical Review, Sept., 1893. Eng. News, Feb. 25, 1904, Vol. 51, p. 185.
Plymouth, Pa.	1885	Water	Sedgwick	Principles of Sanitary Science and the Public Health.
Poughkeepsie, N. Y.	1898–1903	Water	Mann	American Medicine, Vol. VIII, No. 12, Sept. 17, 1904.

PARTIAL LIST OF REFERENCES TO TYPHOID FEVER OUTBREAKS AND EPIDEMICS—*Continued.*

City or Town and State.	Year of Occurrence.	Cause.	Investigator or Author.	Reference.
Rural and Urban Districts, U. S.			Fulton	An. Rept. Maryland St. Bd. of Health, 1903.
Scranton, Pa.	1907	Water	Wainwright	N.Y. Medical Journal, June 1, 1907.
Somerville, Mass.	1892	Milk	Sedgwick	Principles of Sanitary Science and the Public Health.
Springfield, Mass.	1892	Milk	Do.	Do.
Stamford, Conn.	1895	Milk	Smith	An. Rept. Conn. St. Bd. of Health. 1895.
Steamer Northwest, N. Y.	1907	Water		N. Y. Herald, Sept. 21, 25, and 27, 1907.
U. S. Army, U. S.	1898	Contagion	Ried, Vaughan and Shakespeare	House Document No. 757, 58th Congress, 2d Session.
Various epidemics			Soper	Eng. News, Vol. 51, p. 64.
Washington, D. C.		Milk and Contagion	Rosenau, Lumsden and Kastle	Hygienic Laboratory Bulletin No. 35, Public Health and Marine Hospital Service of the U. S.
Do.			Parker	U. S. Geol. Survey, Water Supply and Irrigation Paper, No. 192.
Watertown, N. Y.	1904	Water	Soper	Jour. N. E. W. W. Asso., 1908.
Waterville, Maine	1903	Water	Whipple and Levy	Jour. N. E. W. W. Asso., Vol. 19, p. 163, 1905.
Williams College, Mass.	1903	Cream		Eng. News, Vol. 50, p. 490.
Winnipeg, Manitoba	1904–5	Contagion and Water	Jordan	Report to the City Council.

TABLE I.

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES FOR THE REGISTRATION CITIES OF THE UNITED STATES.

Compiled from the Reports of the Former Department of Labor and the Present Bureau of the Census.

(The death-rates since 1900 are calculated from estimated populations. It will be necessary to revise them after the next census has been taken.)

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Adams (town) . .	Mass.	11,134	12,486	...	...	...	35.1	42.8	25.1	32.7	80.1	31.4
Alameda	Cal.	16,464	19,114	...	...	...	17.6	22.8	33.2	...	36.6	...
Albany	N. Y.	94,151	97,806	100.0	87.1	51.0	21.1	32.4	19.7	17.5	19.4	...
Alexandria	Va.	14,528	14,623	...	...	...	27.5	68.7	61.7	102.7	41.0	41.0
Allegheny	Pa.	129,896	142,848	56.2	104.8	93.3	75.0	121.6	102.9	123.2	126.7	136.3
Allentown	Pa.	35,416	40,571	53.3	62.2	25.4	46.7	189.5	33.8	32.9	41.9	50.5
Altoona	Pa.	38,973	45,557	33.4	33.4	30.8	32.6	24.5	40.7	60.9	68.0	68.9
Amesbury (town) .	Mass.	9,473	8,840	...	...	...	10.7	21.7	33.0	55.8	45.2	45.9
Amsterdam . . .	N. Y.	20,929	23,807	...	...	...	22.4	17.6	47.7	12.8	21.0	...
Anderson	Ind.	20,178	24,898	...	...	...	71.0	68.0	26.1	37.6	24.1	23.2
Ann Arbor	Mich.	14,509	14,622	...	...	...	6.9	20.6	6.9	13.7	13.7	...
Annapolis	Md.	8,525	8,985	...	...	...	23.2	57.4	34.1	67.5	77.9	33.1
Ansonia	Conn.	12,681	13,851	...	...	...	15.5	7.6	44.8	7.3	36.1	...
Appleton	Wis.	15,085	17,000	...	...	...	19.4	18.9	6.2	12.0	17.6	...
Arlington (town) .	Mass.	8,603	9,668	...	...	...	34.0	...	...	...	10.3	...

Ashtabula	Ohio	12,949	15,004	...	...	...	44.9	36.3	49.4	137.1	60.0	38.9
Atlanta	Ga.	89,872	102,702	62.4	85.7	61.3	77.1	68.9	66.3	60.8	70.1	75.2
Atlantic City . . .	N. J.	27,838	37,593	...	...	...	23.5	15.8	38.6	25.3	18.6	...
Attleboro, (town) .	Mass.	11,335	12,702	...	...	...	8.6	8.4	24.7	8.0	7.9	...
Auburn	N. Y.	30,345	32,527	13.2	23.1	46.2	22.7	6.4	25.3	24.9	18.4	...
Augusta	Me.	11,683	12,263	...	...	...	84.8	50.4	232.7	49.4	48.9	56.5
Aurora	Ill.	24,147	26,377	...	...	...	48.8	39.9	15.7	46.3	7.6	...
Baltimore	Md.	508,957	546,217	37.2	30.1	37.1	28.7	42.0	35.0	37.5	35.7	34.3
Bangor	Me.	21,850	23,225	...	...	...	104.0	35.7	44.1	187.4	77.5	42.6
Barre	Vt.	8,448	10,598	...	...	...	22.5	43.0	20.5	...	37.7	...
Bath	Me.	10,477	11,352	...	...	...	9.4	18.5	9.1	26.8	8.8	...
Battle Creek . . .	Mich.	18,563	23,126	...	...	...	56.5	14.7	42.3	22.5	38.9	...
Bay City	Mich.	27,628	40,614	...	...	...	25.3	36.2	54.3	43.4	24.6	49.3
Bayonne	N. J.	32,722	42,262	43.0	4.0	15.0	11.6	24.6	20.8	27.3	11.8	...
Bellaire	Ohio	9,912	9,912	...	...	...	20.2	90.8	60.5	40.4	20.2	90.8
Belleville	Ill.	17,484	18,544	...	...	...	56.5	39.1	77.3	49.1	48.5	26.7
Beloit	Wis.	10,436	12,855	...	...	...	9.2	8.8	16.8	8.1	23.3	...
Bennington . . .	Vt.	5,656	8,853	...	...	...	36.6	12.0	35.3	34.5	67.8	...
Berlin	N. H.	8,886	11,466	...	...	...	63.9	20.2	38.3	54.8	8.7	116.8
Beverly	Mass.	13,884	15,223	...	...	...	7.1	20.8	20.4	13.4	32.8	...
Biddeford	Me.	16,145	16,995	...	...	...	116.5	60.7	54.0	65.4	76.5	17.5
Binghamton . . .	N. Y.	39,647	43,096	70.7	27.8	53.0	52.1	29.2	12.0	9.4	16.2	...
Boston	Mass.	560,892	595,380	33.0	29.4	25.6	23.8	22.1	20.5	23.6	20.8	21.6
Bridgeport	Conn.	70,996	79,848	9.9	11.3	21.1	26.0	23.9	14.2	17.5	13.4	...
Bridgeton	N. J.	13,913	13,682	...	...	...	21.7	21.7	21.8	43.9	29.4	...
Bristol (town) . .	Conn.	6,268	10,547	...	...	...	40.6	19.8	126.0	47.4	18.6	27.3

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Brockton	Mass.	40,063	46,247	7.5	17.5	45.0	14.4	13.9	11.2	19.5	18.8	...
Brookline (town) .	Mass.	19,935	22,735	...	...	...	...	9.4	4.5	4.4	...	...
Buffalo	N. Y.	352,387	372,008	27.8	25.0	27.0	27.1	33.7	34.6	24.2	24.4	23.6
Burlington	Iowa	23,201	24,894	...	...	...	55.0	45.7	45.0	56.2	51.3	...
Burlington	Vt.	18,640	20,260	...	...	...	21.0	10.3	15.1	29.6	19.4	...
Cambridge	Mass.	91,886	96,324	15.2	21.8	16.3	8.6	10.6	10.5	15.6	12.3	...
Camden	N. J.	75,935	81,877	43.5	38.2	15.8	15.5	22.8	13.7	20.8	18.0	...
Canton	Ohio	30,667	32,459	55.5	39.2	22.8	16.1	12.7	21.9	30.8	13.2	...
Carbondale . . .	Pa.	13,536	14,496	...	...	...	14.5	42.8	63.1	34.5	67.9	53.4
Carlisle	Pa.	9,626	10,430	...	...	...	20.4	10.0	48.9	...	18.8	...
Central Falls . . .	R. I.	18,167	19,190	...	...	...	16.3	32.1	10.6	10.4	10.3	...
Charleston	S. C.	55,807	56,147	131.0	109.2	127.0	85.9	80.4	64.2	58.8	53.4	83.5
Chelsea	Mass.	34,072	36,645	20.6	29.4	20.6	28.8	31.1	13.9	32.7	24.1	...
Chicago	Ill.	1,698,575	1,932,315	37.6	26.0	19.9	29.8	45.1	32.1	20.2	16.5	18.3
Chicopee	Mass.	19,167	19,986	...	...	...	25.8	10.2	20.2	10.0	9.9	...
Chillicothe	Ohio	12,976	13,652	...	...	...	76.1	82.6	29.7	95.2	57.9	57.2
Chippewa Falls .	Wis.	8,094		...	...	...	12.1	...	...	...	...	...
Cincinnati	Ohio	325,902	341,444	36.4	37.2	36.6	54.9	61.9	42.7	80.2	41.1	71.5

Cleveland	Ohio	381,768	425,632	31.8	28.6	53.8	34.9	35.5	115.0	49.6	14.9	20.2
Clinton (town)	Mass.	13,667	13,105	...	...	...	29.5	22.3	22.5	30.3	45.8	...
Cohoes	N. Y.	23,910	24,063	...	...	...	66.8	125.2	95.8	104.0	54.0	54.0
Columbia	Pa.	12,316	13,251	...	...	...	80.1	79.0	54.5	122.3	45.3	22.3
Columbus	Ind.	8,130	8,835	...	...	...	36.3	23.8	35.1	103.5	45.3	44.6
Columbus	Ohio	125,560	142,105	26.3	22.3	42.4	48.1	37.1	37.6	147.7	85.1	37.1
Concord	N. H.	19,632	20,947	...	...	...	10.1	14.9	19.6	9.7	9.5	...
Corning	N. Y.	11,061	13,438	...	...	...	34.7	16.7	48.1	54.0	29.8	35.9
Cortland	N. Y.	9,014	11,194	...	...	...	117.6	10.3	38.0	9.2	26.8	...
Covington	Ky.	42,938	45,877	28.0	39.6	49.0	27.6	36.3	35.7	39.7	45.8	...
Danbury (town)	Conn.	16,537	19,474	...	...	...	25.7	15.4	46.2	5.1	25.7	...
Danvers (town)	Mass.	8,542	9,063	...	...	...	...	22.9	11.3	33.5	44.1	...
Davenport	Iowa	35,254	39,797	8.5	42.6	42.3	33.2	29.7	31.6	33.4	15.1	...
Dayton	Ohio	85,333	98,350	21.1	36.4	30.5	34.2	44.4	23.7	27.3	22.4	...
Decatur	Ill.	20,754	24,395	...	...	...	42.8	14.0	18.4	40.8	20.5	...
Denver	Colo.	133,859	150,317	30.6	38.1	41.8	48.7	60.6	55.7	30.3	40.6	68.5
Detroit	Mich.	285,704	325,563	16.9	19.3	18.2	20.1	23.5	20.0	17.6	21.2	22.3
Dover	N. H.	13,207	13,417	...	...	...	37.7	7.5	22.5	22.4	44.7	...
Dubois	Pa.	9,375	10,990	...	...	...	20.6	59.9	38.7	65.6	27.3	44.2
Duluth	Minn.	52,969	64,942	49.1	37.8	94.5	74.1	53.7	64.8	54.4	44.7	46.0
Dunkirk	N. Y.	11,616	15,197	...	...	...	24.3	76.6	50.9	41.4	46.1	37.7
Eau Claire	Wis.	17,517	18,737	...	...	...	5.6	16.7	11.0	5.4	16.0	...
Elizabeth	N. J.	52,130	60,509	13.4	17.2	7.7	27.9	27.0	21.0	18.7	8.3	...
Elkhart	Ind.	15,184	17,119	...	...	...	32.1	56.3	55.0	47.8	52.6	11.4
Elmira	N. Y.	35,672	35,724	47.7	30.9	47.7	28.0	36.4	86.8	53.2	28.0	47.6
Elwood	Ind.	12,950	18,185	...	...	...	57.2	59.8	49.7	40.9	49.5	46.8

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Erie	Pa.	52,733	58,783	13.3	34.2	34.2	16.7	25.4	33.7	48.6	17.0	...
Escanaba	Mich.	9,549	11,485	...	...	...	50.3	67.8	28.0	351.4	182.8	101.1
Evansville	Ind.	59,007	63,132	47.5	66.1	62.8	26.7	42.9	27.7	40.1	42.8	...
Everett	Mass.	24,336	29,111	...	...	...	7.9	26.7	7.4	10.7	24.0	...
Fall River	Mass.	104,863	105,762	20.0	10.5	14.3	25.7	11.4	22.8	18.9	11.3	7.6
Findlay	Ohio	17,613	17,613	...	...	...	34.1	34.1	34.1	45.4	39.7	...
Fitchburg	Mass.	31,531	33,021	19.0	12.7	31.7	22.0	12.5	3.1	9.2	12.1	...
Flint	Mich.	13,103	15,229	...	...	...	36.1	49.3	68.8	20.2	19.7	38.5
Fort Wayne	Ind.	45,115	49,975	...	33.3	35.4	36.9	27.6	39.6	30.6	16.0	...
Framingham (town)	Mass.	11,302	11,548	...	...	...	...	35.1	8.7	8.7	26.0	...
Frederick	Md.	9,296	9,846	...	...	...	31.9	63.0	31.2	61.6	10.2	60.3
Fresno	Cal.	12,470	13,295	...	...	...	182.0	117.2	123.4	60.9	82.7	170.9
Gardner (town)	Mass.	10,813	12,012	...	...	...	54.3	26.6	8.7	25.5	8.3	...
Geneva	N. Y.	10,433	12,161	...	...	...	55.7	9.0	43.6	50.8	32.9	40.0
Glens Falls	N. Y.	12,613	14,650	...	...	...	84.5	14.9	28.9	49.2	20.5	53.1
Gloucester	Mass.	26,121	26,011	...	...	...	19.2	15.3	26.9	15.4	23.1	...
Gloversville	N. Y.	18,349	18,578	...	...	...	5.4	27.1	16.2	5.4	21.5	...
Grand Rapids	Mich.	87,565	97,756	32.0	29.7	42.3	33.5	51.3	41.6	61.6	49.1	39.1

Green Bay	Wis.	18,684	22,854	...	...	...	41.0	19.7	9.4	36.3	30.6	...
Greenwich (town).	Conn.	12,172	13,192	...	...	...	8.1	23.8	39.1	15.4	37.9	...
Hamilton	Ohio	23,914	27,044	...	...	...	24.5	43.7	42.6	26.5	14.8	54.2
Hammond	Ind.	12,376	15,526	...	...	...	92.3	66.0	126.2	40.3	64.4	62.7
Harrisburg	Pa.	50,167	54,807	31.9	39.9	47.9	66.5	63.4	103.9	59.4	69.3	66.4
Harrison	N. J.	10,596	12,823	...	...	...	9.1	34.8	25.1	8.1	...	...
Hartford	Conn.	79,850	93,160	45.0	47.6	43.9	43.6	16.4	21.6	13.3	17.2	...
Haverhill	Mass.	37,175	37,830	21.6	13.5	16.2	24.1	26.7	13.3	13.3	21.1	...
Hazelton	Pa.	14,230	15,533	...	...	...	27.4	20.2	19.9	13.1	32.2	...
Hoboken	N. J.	59,364	65,468	13.5	30.4	16.8	26.4	9.7	15.9	20.2	13.7	...
Holyoke	Mass.	45,712	49,934	17.5	24.1	19.7	15.0	16.9	10.4	8.1	8.0	...
Hudson	N. Y.	9,528	10,364	...	...	...	61.9	71.0	39.9	166.7	48.2	38.0
Huntington . . .	Ind.	9,491	10,541	...	...	...	82.3	20.1	49.5	38.7	47.4	...
Hyde Park (town).	Mass.	13,244	14,510	...	...	...	22.2	14.5	14.3	7.0	13.8	...
Indianapolis . . .	Ind.	169,164	212,198	28.4	37.8	43.7	33.1	44.5	51.1	68.4	30.2	39.2
Iron Mountain . .	Mich.	9,242	8,421	...	...	...	...	...	11.4	11.6	23.8	...
Ironton	Ohio	11,868	12,133	...	...	...	58.7	66.8	66.5	33.1	65.9	90.3
Ironwood	Mich.	9,705	10,098	...	...	...	30.7	40.6	...	39.9	59.4	39.3
Ishpeming	Mich.	13,255	11,215	...	...	...	23.3	8.0	33.2	...	8.9	...
Ithaca	N. Y.	13,136	14,496	...	...	...	44.7	7.3	336.9	28.1	13.8	20.3
Jackson	Mich.	25,180	25,330	...	...	...	55.5	55.5	23.8	47.4	63.2	23.7
Jacksonville . . .	Fla.	28,429	35,301	...	...	...	53.7	128.3	61.4	85.5	93.5	76.3
Jacksonville . . .	Ill.	15,078	16,148	...	...	...	32.7	96.7	101.8	56.5	31.0	18.3
Jamestown . . .	N. Y.	22,892	26,005	...	...	...	21.3	4.1	24.2	39.4	30.8	...
Jeffersonville . . .	Ind.	10,774	10,829	...	...	...	111.3	37.0	64.8	46.2	27.7	55.4
Jersey City . . .	N. J.	206,433	232,699	34.4	14.5	21.4	16.1	20.3	14.9	18.9	19.8	20.2

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Johnstown	N. Y.	10,130	9,765	...	...	...	...	20.0	40.4	...	10.2	...
Johnstown	Pa.	35,936	42,160	27.0	78.0	139.4	116.4	36.0	22.5	34.1	45.1	55.5
Kalamazoo . . .	Mich.	22,404	31,127	...	...	...	27.2	18.5	38.7	20.1	19.3	...
Kansas City . . .	Mo.	163,752	179,272	25.1	30.6	36.0	45.5	38.2	80.3	43.1	61.4	37.8
Keene	N. H.	9,165	10,025	...	...	...	21.4	10.5	10.3	10.1	39.9	...
Key West	Fla.	17,114	20,498	...	...	...	28.1	43.3	10.4	85.8	58.5	28.3
Kingston	N. Y.	24,535	25,410	...	...	...	12.1	16.1	27.9	19.8	31.5	...
Kokomo	Ind.	10,609	11,784	...	...	...	36.9	45.1	17.7	8.7	25.5	...
Laconia	N. H.	8,042	8,042	...	...	...	24.9	24.9	12.4	12.4	...	...
Lafayette	Ind.	18,116	19,051	...	...	...	43.7	81.1	26.8	37.1	68.2	41.6
Lancaster	Pa.	41,459	46,184	62.8	67.6	41.0	21.2	50.8	51.9	79.6	43.3	78.5
Lansing	Mich.	16,485	21,224	...	...	...	34 4	10.9	62.1	44.4	42.4	76.7
Lawrence	Mass.	62,559	70,050	17.6	31.9	22.4	18.7	19.8	28.3	17.5	22.8	...
Leadville	Colo.	12,445	13,490	...	...	...	55.5	38.9	22.9	286.1	14.8	36.5
Leavenworth . . .	Kans.	20,735	20,934	...	...	...	58.1	84.7	52.2	48.3	33.4	22.6
Leominster (town)	Mass.	12,392	14,297	...	...	...	15.7	7.6	7.4	7.2	7.0	...
Lima	Ohio	21,723	27,048	...	...	...	58.3	24.1	31.3	34.1	22.2	...
Lincoln	Nebr.	40,169	46,874	17.5	22.4	14.9	36.2	39.1	15.8	22.0	25.5	...

Lockport	N. Y.	16,581	17,428	...	...	...	83.6	29.6	52.7	40.6	63.1	62.5
Logansport . . .	Ind.	16,204	17,644	...	...	...	48.5	29.8	52.7	51.9	73.7	61.3
Louisville	Ky.	204,731	222,660	57.7	59.8	57.8	46.0	60.3	59.8	61.6	49.4	67.7
Lowell	Mass.	94,969	94,889	25.6	17.9	17.9	20.0	17.9	32.7	20.0	19.0	...
Lynchburg	Va.	18,891	22,350	...	...	...	78.6	105.5	74.9	114.4	58.2	65.6
Lynn	Mass.	68,513	77,042	21.9	19.0	19.0	14.2	12.5	17.7	23.9	23.4	...
McKeesport . . .	Pa.	34,227	42,024	43.8	40.9	67.3	81.5	81.3	81.0	133.6	85.7	142.7
Madison	Wis.	19,164	24,301	...	...	...	5.0	...	...	...	4.1	...
Mahanoy City . .	Pa.	13,504	14,614	...	...	...	7.3	21.5	14.1	13.9	34.2	...
Malden	Mass.	33,664	38,037	14.9	11.9	20.8	29.0	25.4	19.3	26.9	10.5	...
Manchester . . .	N. H.	56,987	63,417	24.6	21.1	10.5	17.2	15.1	18.1	20.9	18.9	...
Manchester (town)	Conn.	10,601	11,791	...	...	...	...	...	26.5	26.0	33.9	...
Manitowoc	Wis.	11,786	12,733	...	...	...	25.1	...	8.1	15.9	15.7	...
Mankato	Minn.	10,599	10,996	...	...	...	18.7	9.3	...	18.3	36.4	...
Marietta	Ohio	13,348	15,888	...	...	...	115.5	90.5	74.0	65.0	31.5	18.3
Marinette	Wis.	16,195	15,354	...	...	...	31.2	31.5	51.0	25.8	39.1	26.3
Marion	Ind.	17,337	23,056	...	...	...	82.4	78.8	23.7	63.4	47.7	25.0
Marlboro	Mass.	13,609	14,073	...	...	...	...	7.2	7.2	14.3	7.1	...
Marquette	Mich.	10,058	10,817	...	...	...	19.6	57.9	28.5	37.5	37.0	36.5
Massillon	Ohio	11,944	12,869	...	...	...	33.0	16.2	16.0	15.8	46.6	...
Meadville	Pa.	10,291	11,684	...	...	...	86.8	105.3	47.5	17.2	34.2	34.0
Medford	Mass.	18,244	19,686	...	...	...	5.4	15.9	15.7	10.3	15.2	...
Melrose	Mass.	12,962	14,295	...	...	...	30.2	7.4	7.3	7.1	...	...
Memphis	Tenn.	102,320	121,235	22.4	38.1	35.1	51.8	39.1	41.3	46.0	33.8	42.4
Menominee . . .	Mich.	12,818	10,665	...	...	...	56.5	25.1	86.8	117.2	46.9	78.2
Meriden (town) .	Conn.	24,296	30,330	...	...	...	17.2	6.8	33.7	6.7	9.9	...

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Michigan City	Ind.	14,850	16,885	...	...	...	13.1	31.9	68.4	54.6	35.5	34.7
Middletown	N. Y.	14,522	15,682	...	...	...	40.7	53.4	19.7	6.5	38.3	25.1
Middletown	Ohio	9,215	9,290	...	...	...	32.5	10.8	21.6	10.8	...	...
Middletown	Conn.	9,589	18,626	...	...	...	39.5	5.6	22.0	5.4	...	...
Milford (town)	Mass.	11,376	12,105	...	...	...	8.7	17.1	8.5	8.4	...	...
Millville	N. J.	10,583	11,884	...	...	...	27.7	45.0	35.2	25.8	16.8	...
Milwaukee	Wis.	285,315	312,948	16.1	16.5	20.7	22.1	15.1	16.8	13.6	22.7	30.5
Minneapolis	Minn.	202,718	261,974	42.4	34.8	38.6	58.7	26.9	41.1	40.4	24.4	32.9
Mobile	Ala.	38,469	42,164	59.9	54.7	67.6	68.9	80.1	51.6	57.9	106.7	35.0
Montclair	N. J.	13,962	16,370	...	...	...	13.8	13.4	19.5	44.1	18.3	...
Morristown	N. J.	11,267	12,146	...	...	...	35.0	34.4	17.0	16.7	90.6	56.8
Mt. Carmel	Pa.	13,179	15,644	...	...	...	...	7.0	...	6.6	...	...
Mt. Vernon	N. Y.	21,228	24,930	...	...	...	13.7	8.8	4.3	24.8	24.1	...
Muncie	Ind.	20,942	26,301	...	...	...	86.4	95.5	16.4	63.2	76.0	33.0
Muscatine	Iowa	14,073	15,087	...	...	...	35.0	41.4	88.5	100.8	59.7	...
Muskegon	Mich.	20,818	20,917	...	...	...	19.2	14.4	19.2	28.7	28.7	...
Nashua	N. H.	23,898	26,193	...	...	...	8.2	12.1	15.8	19.4	7.6	...
Nashville	Tenn.	80,865	84,227	27.2	61.9	48.3	43.0	51.4	69.7	54.9	71.2	74.4

Natick (town) . .	Mass.	9,488	9,609	...	...	...	10.5	41.9	10.5	10.4	...	...
Naugatuck	Conn.	10,541	12,701	...	...	...	18.2	26.3	16.9	16.3	7.9	...
New Albany . . .	Ind.	20,628	20,628	...	...	...	34.0	29.1	87.3	14.5	67.9	33.9
New Bedford . . .	Mass.	62,442	74,362	27.3	25.6	35.2	30.9	35.7	50.3	20.8	8.1	10.4
New Britain (town)	Conn.	25,998	32,802	...	...	...	20.6	13.3	19.4	22.0	18.3	...
New Brunswick . .	N. J.	20,006	23,133	...	...	...	29.1	14.1	4.6	35.5	34.6	...
New Haven . . .	Conn.	108,027	119,027	36.1	25.9	25.9	94.4	39.1	36.6	27.4	42.8	53.6
New London . . .	Conn.	17,548	19,443	...	...	...	11.2	38.2	16.0	5.2	30.9	...
New Orleans . . .	La.	287,104	309,639	64.1	54.0	39.7	50.1	44.2	40.9	36.7	32.6	29.6
New Rochelle . .	N. Y.	14,720	20,387	...	...	...	37.8	23.5	22.1	15.6	19.6	...
New York	N. Y.	3,437,202	4,000,403	20.7	16.3	20.8	20.6	20.3	17.1	16.8	16.0	15.4
Bronx (borough)	N. Y.	200,507	271,592	13.5	8.7	14.8	16.3	15.7	14.8	12.0	14.4	15.0
Brooklyn "	N. Y.	1,166,582	1,355,106	24.6	18.1	25.7	22.4	24.3	19.4	22.4	21.3	16.2
Manhattan"	N. Y.	1,850,093	2,102,928	19.5	15.2	18.5	19.9	18.5	15.9	13.4	12.7	15.0
Queens "	N. Y.	152,999	197,838	11.7	18.6	20.8	17.9	21.1	16.1	19.6	17.7	14.5
Richmond "	N. Y.	67,021	72,939	22.0	30.6	19.9	26.4	14.4	19.8	20.9	15.1	13.5
Newark	N. J.	246,070	283,289	16.7	26.8	20.3	23.8	19.6	22.9	13.6	14.1	17.6
Newark	Ohio	18,157	20,102	...	...	...	26.9	47.5	25.9	10.1	54.7	29.3
Newburg	N. Y.	24,943	26,318	...	...	...	31.7	47.1	38.8	42.2	41.8	...
Newburyport . . .	Mass.	14,478	14,675	...	...	...	41.3	48.1	13.7	20.5	61.3	54.4
Newcastle	Pa.	28,339	35,429	...	...	...	57.1	192.5	122.7	64.7	50.8	32.6
Newport	Ky.	28,301	29,991	...	...	...	7.0	13.8	30.7	33.7	33.3	59.3
Newport	R. I.	22,034	25,039	...	...	...	39.2	29.8	16.7	16.3	24.0	...
Newton	Mass.	33,587	36,827	20.9	11.9	26.8	17.5	5.7	8.4	8.3	10.8	...
Niagara Falls . .	N. Y.	19,457	26,432	...	...	...	143.9	130.4	126.9	139.8	181.6	147.3
Norfolk	Va.	46,624	58,006	64.4	77.2	45.0	33.5	51.9	59.7	58.2	37.9	73.2

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Norristown	Pa.	22,265	23,500	...	...	...	71.1	48.3	52.2	77.4	46.8	71.6
North Adams	Mass.	24,200	22,150	...	...	...	21.0	55.6	56.6	44.3	13.5	32.2
Northampton	Mass.	18,643	19,957	...	...	...	21.2	5.2	10.3	15.2	20.0	...
Norwalk (town)	Conn.	6,125	21,027	...	...	...	54.6	54.0	24.3	24.0	23.8	28.2
Norwich (town)	Conn.	17,251	25,432	...	...	...	12.1	20.0	15.9	7.9	11.8	...
Oakland	Cal.	66,960	72,670	13.5	35.9	19.5	11.7	23.1	21.3	43.3	35.8	...
Ogdensburg	N. Y.	12,633	14,815	...	...	...	20.4	95.0	54.2	60.9	40.5	87.6
Olean	N. Y.	9,462	10,079	...	...	...	10.4	41.2	30.5	20.1	...	...
Omaha	Nebr.	102,555	120,565	31.2	25.4	23.4	24.5	21.9	11.5	17.1	24.9	28.2
Orange	N. J.	24,141	26,101	...	...	...	12.2	40.1	19.7	19.4	23.0	...
Ottawa	Ill.	10,588	11,088	...	...	...	56.1	18.5	9.2	9.1	18.0	...
Ottumwa	Iowa	18,197	...	...	...	...	59.3	47.5	36.0	...	...	...
Owosso	Mich.	8,696	9,257	...	...	...	22.7	44.8	...	...	10.8	...
Paducah	Ky.	19,446	21,961	...	...	...	75.2	92.9	42.9	60.6	91.1	62.3
Passaic	N. J.	27,777	37,837	...	...	...	16.7	9.4	14.1	16.7	7.9	...
Paterson	N. J.	105,171	111,529	33.3	46.5	22.8	23.5	34.4	22.0	7.3	14.3	4.4
Pawtucket	R. I.	39,231	43,381	20.4	25.5	20.4	12.5	24.5	19.2	23.5	6.9	...
Peabody (town)	Mass.	11,523	13,098	...	...	...	...	8.2	...	15.6	7.6	...

Peekskill	N. Y.	10,358	13,200	...	...	...	18.3	26.1	41.5	7.9	15.2	...
Perth Amboy . .	N. J.	17,699	25,895	...	...	...	15.5	19.1	8.8	28.9	15.4	...
Peru	Ind.	8,463	11,347	...	...	...	75.4	55.6	72.9	53.7	35.3	17.2
Petersburg	Va.	21,810	21,810	...	...	...	82.5	96.3	96.3	105.5	64.2	137.6
Philadelphia . . .	Pa.	1,293,697	1,417,062	49.4	73.4	34.7	34.6	47.3	72.6	55.0	51.1	74.8
Phillipsburg . . .	N. J.	10,052	13,352	...	...	...	28.8	102.1	7.9	15.4	22.5	...
Pittsburg	Pa.	321,616	364,161	68.0	106.9	144.2	123.8	140.6	136.5	139.4	107.9	141.3
Pittsfield	Mass.	21,766	25,001	...	...	...	31.2	21.7	25.3	32.8	40.0	...
Plainfield	N. J.	15,369	18,468	...	...	...	43.8	12.0	29.0	50.4	16.2	10.5
Plymouth	Pa.	13,649	15,804	...	...	...	35.5	27.6	13.4	6.5	31.6	...
Plymouth (town) .	Mass.	9,592	11,119	...	...	...	...	19.6	...	55.5	18.0	8.8
Pontiac	Mich.	9,769	11,163	...	...	...	49.8	9.7	9.4	18.4	26.9	...
Port Huron . . .	Mich.	19,158	20,246	...	...	...	41.3	61.2	25.2	34.9	14.8	53.8
Port Jervis . . .	N. Y.	9,385	9,695	...	...	...	31.8	52.6	62.7	83.0	92.8	41.0
Portland	Me.	50,145	54,330	71.8	29.9	31.9	29.4	28.9	32.3	28.0	25.8	...
Portland	Oreg.	90,426	104,141	22.1	23.2	26.6	21.5	36.5	35.5	25.6	34.6	...
Portsmouth . . .	N. H.	10,637	11,042	...	...	...	18.7	55.6	36.8	9.1	...	27.0
Portsmouth . . .	Ohio	17,870	20,240	...	...	...	60.0	69.1	88.1	75.9	79.0	57.9
Pottstown	Pa.	13,696	13,901	...	...	...	29.1	43.5	79.6	86.6	57.5	28.7
Pottsville	Pa.	15,710	16,505	...	...	...	12.6	49.9	37.1	12.2	54.5	42.0
Poughkeepsie . .	N. Y.	24,029	25,146	...	...	...	45.4	24.5	44.5	64.2	47.7	43.4
Providence	R. I.	175,597	198,635	22.2	24.5	23.4	25.0	21.1	19.5	15.5	20.1	19.2
Pueblo	Colo.	28,157	30,457	...	...	...	101.7	311.7	184.7	111.5	68.9	113.5
Quincy	Ill.	36,252	38,632	35.9	24.8	44.2	40.8	56.4	39.8	52.4	25.9	33.2
Quincy	Mass.	23,899	28,076	...	...	...	8.1	19.6	7.6	3.7	10.7	...
Raleigh	N. C.	13,643	14,128	...	...	...	87.3	65.0	71.8	57.0	42.5	70.3

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Reading	Pa.	78,961	89,111	64.7	33.0	49.5	53.1	66.2	31.7	33.3	25.8	39.5
Revere (town) . .	Mass.	10,395	12,659	...	...	...	9.2	17.7	17.0	8.2	15.8	...
Richmond	Ind.	18,226	19,436	...	...	...	27.2	59.3	26.7	26.5	5.1	25.5
Richmond	Va.	85,050	86,880	34.1	43.5	88.3	51.5	72.3	73.1	54.3	44.9	47.0
Rochester	N. H.	8,466	9,001	...	...	...	11.7	23.1	34.1	22.5	22.2	...
Rochester	N. Y.	162,608	182,022	13.5	18.5	18.5	17.4	11.8	12.1	15.8	11.5	17.2
Rockland	Me.	8,150	8,150	...	...	...	12.3	12.3	12.3	24.5	12.3	...
Rome	N. Y.	15,343	17,329	...	...	...	19.1	24.8	18.1	17.7	40.4	...
Rutland	Vt.	11,499	11,884	...	...	...	8.6	17.2	34.1	25.4	33.7	...
Sacramento . . .	Cal.	29,282	30,732	...	...	...	84.5	36.8	49.8	75.6	61.8	48.4
Saginaw	Mich.	42,345	47,676	14.2	26.0	35.5	27.6	9.0	11.0	49.3	25.2	...
St. Joseph	Mo.	102,979	115,479	11.6	34.0	6.7	14.2	13.9	8.1	12.4	7.8	11.9
St. Louis	Mo.	575,238	636,973	16.5	22.8	29.2	33.4	40.0	52.4	37.9	22.6	18.3
St. Paul	Minn.	163,065	197,023	26.3	18.3	22.1	13.5	13.6	10.4	13.7	10.7	21.1
Salem	Mass.	35,956	37,627	27.8	19.5	19.5	24.8	24.6	46.0	21.5	26.6	...
Salt Lake City . .	Utah	53,531	58,914	43.0	20.6	26.2	79.0	72.4	61.3	74.1	101.8	67.0
San Antonio . . .	Tex.	53,321	61,146	...	43.2	89.9	61.9	65.5	62.0	50.4	44.2	28.7
San Diego	Cal.	17,700	18,900	...	...	...	39.0	5.5	10.9	16.1	15.9	...

San Francisco	Cal.	342,782	364,677	16.7	51.2	41.3	25.1	29.6	25.0	31.4	23.9	...
San Jose	Cal.	21,500	23,220	...	...	...	13.7	4.5	31.1	21.8	12.9	...
Saratoga Springs	N. Y.	12,409	12,999	...	...	...	71.8	23.7	47.0	46.6	38.5	...
Sault Ste Marie	Mich.	10,538	11,668	...	...	...	92.9	172.9	115.9	52.4	68.6	58.9
Savannah	Ga.	54,244	67,311	36.9	35.1	29.6	28.9	44.1	54.1	78.8	40.1	40.8
Schenectady	N. Y.	31,682	58,213	4.0	...	38.0	36.7	19.1	31.5	22.0	6.9	...
Scranton	Pa.	102,026	116,111	13.7	24.5	29.4	34.4	19.6	18.2	10.7	17.2	61.5
Seattle	Wash.	80,671	99,586	29.8	31.0	29.8	30.8	32.9	36.9	36.5	36.1	...
Sioux City	Iowa	33,111	40,952	21.1	9.7	39.3	14.4	24.8	18.5	17.8	24.4	...
Somerville	Mass.	61,643	69,272	17.9	24.4	14.6	19.0	7.7	13.6	17.7	13.0	...
South Bend	Ind.	35,999	43,204	25.1	...	44.6	29.4	28.3	14.9	16.8	27.8	...
South Bethlehem	Pa.	13,241	14,711	...	...	...	29.6	57.8	205.3	48.5	13.6	20.0
Southbridge (town)	Mass.	10,025	11,000	...	...	...	19.6	57.6	9.4	...	36.4	35.7
Spokane	Wash.	36,848	45,313	51.6	46.2	65.3	51.9	47.2	88.2	80.3	86.1	97.9
Springfield	Ill.	34,159	38,234	41.0	58.6	29.3	25.8	31.0	49.7	40.0	36.6	...
Springfield	Mass.	62,059	73,540	24.2	24.2	27.4	28.0	19.5	23.2	15.4	27.2	...
Stamford town	Conn.	15,997	20,409	...	...	...	15.7	61.7	50.5	29.9	29.4	14.5
Steelton	Pa.	12,086	13,624	...	...	...	32.3	276.6	184.1	52.5	51.4	122.2
Stonington	Conn.	2,278	9,220	...	...	...	...	...	44.7	33.0	...	...
Superior	Wis.	31,091	36,551	25.8	32.2	125.9	49.7	33.1	49.5	33.8	30.1	93.0
Syracuse	N. Y.	108,374	117,129	43.3	18.4	28.6	19.1	8.0	17.6	18.2	17.1	10.1
Tacoma	Wash.	37,714	51,962	39.8	13.2	21.2	29.9	35.1	59.9	61.8	23.1	39.7
Taunton	Mass.	31,036	30,967	25.8	22.6	25.8	29.0	22.6	19.4	6.5	9.7	...
Terre Haute	Ind.	36,673	51,903	40.9	57.4	71.0	75.0	44.8	57.0	61.1	48.2	47.3
Tiffin	Ohio	10,989	11,059	...	...	...	9.1	18.2	27.2	54.3	18.1	...
Toledo	Ohio	131,822	155,287	23.6	30.4	38.7	32.2	34.7	29.5	37.2	45.7	45.0

TABLE OF POPULATIONS AND TYPHOID FEVER DEATH-RATES — Continued.

City.	State.	Population.		Typhoid Fever Death-rate per 100,000.								
		1900 Census.	1905 U. S. Census Estimate.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Torrington	Conn.	8,360	15,658	...	...	...	7.6	...	13.9	6.7	19.2	...
Traverse City. . .	Mich.	9,407	11,695	...	...	...	30.4	19.4	...	35.6	25.7	90.5
Trenton	N. J.	73,307	84,180	30.0	45.0	31.4	18.5	39.9	60.1	42.7	24.9	34.7
Troy	N. Y.	60,651	76,271	72.8	76.0	155.0	57.1	49.0	35.6	50.0	51.1	34.0
Union	N. J.	15,187	17,005	...	...	...	6.4	25.1	6.1	12.0	17.6	...
Utica	N. Y.	56,383	63,647	21.3	17.7	24.8	15.6	16.9	18.1	17.7	12.6	...
Vernon (town) . .	Conn.	8,483	8,318	...	...	...	11.8	11.9	...	23.9	24.0	...
Vincennes	Ind.	10,249	11,155	...	...	...	38.5	57.0	55.2	118.1	53.8	17.6
Wabash	Ind.	8,618	9,723	...	...	...	67.9	77.3	21.5	21.0	...	10.1
Wakefield (town) .	Mass.	9,290	10,268	...	...	...	21.1	20.7	10.1	...	9.7	...
Wallingford (town)	Conn.	6,737	10,211	...	...	...	...	...	10.3	20.1	9.8	...
Waltham	Mass.	23,481	26,282	...	...	...	29.1	40.6	31.8	15.6	53.3	22.4
Ware (town) . . .	Mass.	8,263	8,594	...	...	...	12.0	...	...	...	...	...
Washington . . .	D. C.	278,718	302,883	60.6	60.7	77.8	61.4	79.1	48.8	47.0	48.2	52.3
Washington . . .	Ind.	8,551	9,796	...	...	...	125.0	22.1	43.0	41.9	71.5	79.5
Waterbury (town).	Conn.	45,859	60,109	28.4	32.7	54.5	32.1	32.9	30.1	20.6	31.6	...
Watertown	N. Y.	21,696	25,276	...	...	...	49.1	64.9	71.3	211.7	23.7	46.2
Watertown (town)	Mass.	9,706	11,258	...	...	...	10.0	...	18.8	...	...	...

Watervliet	N. Y.	14,321	14,481	...	...	...	55.7	62.6	69.4	48.4	55.2	48.2
Webster (town). .	Mass.	8,804	10,018	...	...	...	22.1	10.8	...	10.2	20.0	...
West Bay City . .	Mich.	13,119	...	...	...	...	15.3	15.3	23.0	53.9	...	...
Westfield (town) .	Mass.	12,310	13,611	...	...	...	...	23.4	30.6	37.5	22.0	...
Weymouth	Mass.	11,324	11,585	...	...	...	26.4	26.3	8.7	8.7	...	...
Wheeling	W. Va.	38,878	41,058	84.8	69.6	90.2	86.5	95.6	97.0	78.8	85.2	125.3
Wichita	Kans.	24,671	31,110	...	...	...	114.4	85.2	44.4	28.3	38.6	28.1
Williamsport . . .	Pa.	28,757	29,572	...	...	...	17.3	51.6	30.8	40.8	71.0	47.1
Wilmington. . . .	Del.	76,508	83,860	35.3	60.0	47.0	41.2	60.7	94.7	50.9	35.8	45.8
Wilmington. . . .	N. C.	20,976	21,436	...	...	...	90.2	89.8	56.5	75.0	79.3	92.9
Windham (town) .	Conn.	10,100	10,192	...	...	...	19.7	9.8	29.5	19.6	29.4	...
Winona	Minn.	19,714	20,334	...	...	...	10.1	5.0	14.9	9.9	9.8	...
Woburn	Mass.	14,254	14,402	...	...	...	14.0	...	...	...	27.8	...
Woonsocket . . .	R. I.	28,204	32,196	...	...	...	10.3	3.4	3.3	6.4	12.4	...
Worcester	Mass.	118,421	128,135	11.0	16.0	27.0	21.6	13.9	15.3	6.3	21.1	11.5
Yonkers	N. Y.	47,931	61,414	12.5	10.4	10.4	19.8	11.3	14.3	15.3	4.9	...
Youngstown . . .	Ohio	44,885	51,516	...	120.2	87.0	136.8	135.5	180.0	89.8	67.9	66.4

ADDENDA.

		1906			1906			1906
Alpena.	Mich.	55.1	Cumberland	Md.	121.4	Phoenixville	Pa.	83.3
Beaver Falls	Pa.	117.1	Danville	Pa.	62.0	Sharon	Pa.	109.2
Braddock	Pa.	119.7	Dunmore	Pa.	66.0	Oswego	N. Y.	66.9
Butler	Pa.	99.0	Duquesne	Pa.	111.7	West Chester	Pa.	95.9
Chester	Pa.	65.8	Nanticoke	Pa.	52.4	Wilkinsburg	Pa.	188.8

TABLE II.—BOSTON, MASS., TABLE OF STATISTICS OF TYPHOID FEVER FROM 1810–1906.

(Illustrating Chronological Distribution.)

Year.	Population.	Typhoid Fever.		Typhus Fever.	
		Deaths.	Rate per 100,000.	Deaths.	Rate per 100,000.
1810	33,787	...	...	...	...
1811	34,738	...	...	63	181.5
1812	35,689	...	...	23	64.4
1813	36,640	...	...	42	124.5
1814	37,591	...	...	80	202.8
1815	38,542	...	...	51	132.5
1816	39,493	...	...	23	58.3
1817	40,444	...	...	59	146.2
1818	41,395	...	...	119	287.0
1819	42,346	...	...	112	265.0
1820	43,298	...	...	51	117.8
1821	45,107	...	...	45	99.8
1822	46,916	...	...	34	72.4
1823	48,725	...	...	43	88.3
1824	50,534	...	...	62	122.8
1825	52,343	...	...	54	103.2
1826	54,152	...	...	50	92.4
1827	55,961	...	...	46	80.8
1828	57,770	...	...	46	79.9
1829	59,579	...	...	45	75.6
1830	61,392	...	...	33	53.7
1831	63,684	...	...	43	67.9
1832	65,976	...	...	60	91.1
1833	68,268	...	...	73	106.8
1834	70,560	...	...	70	98.4
1835	72,852	...	...	101	138.6
1836	75,144	...	...	68	90.5
1837	77,436	...	...	93	120.3
1838	79,728	...	...	42	42.7
1839	82,020	...	...	60	73.2
1840	84,311	...	...	69	81.8
1841	89,614	...	...	45	50.2
1842	95,251	...	...	65	68.2
1843	101,242	...	...	72	71.1
1844	107,610	...	...	73	67.8

TABLE II.—TABLE OF STATISTICS OF TYPHOID FEVER.—*Continued.*

Years.	Population.	Typhoid Fever.		Typhus Fever.	
		Deaths.	Rate per 100,000.	Deaths.	Rate per 100,000.
1845	114,366	...	...	97	84.8
1846	118,551	...	...	133	112.2
1847	122,890	...	...	166	541.9
1848	127,387	...	...	258	202.5
1849	132,048	...	...	119	90.1
1850	136,881	...	...	61	44.6
1851	141,308	...	...	88	62.2
1852	145,878	...	...	46	31.5
1853	150,595	...	...	44	29.2
1854	155,464	...	...	38	24.4
1855	160,494	...	...	12	7.5
1856	163,820	70	42.7	6	3.7
1857	167,218	83	49.6	3	1.8
1858	170,685	73	42.9	2	1.1
1859	174,227	74	42.5	...	...
1860	177,840	110	61.8	...	...
1861	180,646	96	53.1	...	...
1862	183,497	85	46.3	...	...
1863	186,390	130	69.7	...	...
1864	189,331	107	56.5	10	5.3
1865	192,318	125	65.0	12	6.2
1866	194,506	93	47.8	8	4.1
1867	227,523	86	37.8	3	1.3
1868	231,024	120	51.9	1	0.4
1869	246,541	138	56.0	.	...
1870	250,526	168	67.1	...	...
1871	258,032	176	68.2	...	...
1872	265,764	229	86.2	...	...
1873	321,200	243	75.6	...	...
1874	331,395	202	61.0	...	...
1875	341,919	727	66.4	...	...
1876	346,004	145	41.9	...	...
1877	350,138	156	44.6	2	0.6
1878	354,322	120	33.9	...	...
1879	358,554	119	33.2	1	0.3
1880	362,839	154	42.4	...	...
1881	368,190	207	56.2	...	...
1882	373,620	212	56.7	...	...

TABLE II.—TABLE OF STATISTICS OF TYPHOID FEVER.—*Continued.*

Years.	Population.	Typhoid Fever.		Typhus Fever.	
		Deaths.	Rate per 100,000.	Deaths.	Rate per 100,000.
1883	379,129	198	52.2	2	0.5
1884	384,720	216	56.1	1	0.3
1885	390,393	152	38.9	...	...
1886	401,374	135	33.6	...	...
1887	412,663	183	44.3	...	...
1888	424,274	170	40.1	1	0.2
1889	436,208	186	42.6	...	...
1890	448,477	155	34.6	...	...
1891	457,772	154	33.6	...	...
1892	467,260	137	29.3	...	...
1893	476,945	148	31.0	...	...
1894	486,830	141	29.0	...	...
1895	501,083	163	32.5	...	...
1896	516,305	162	31.4	...	...
1897	528,912	173	32.7	...	...
1898	541,827	185	34.0	...	...
1899	555,057	165	29.7	...	...
1900	560,892	143	25.5	...	...
1901	567,617	142	25.0	...	...
1902	574,465	139	24.2	...	...
1903	581,357	119	20.5	...	...
1904	588,320	135	22.9	...	...
1905	595,380	117	19.6	...	...
1906	602,440	122	20.3	...	...

The data for the years before 1845 are taken from the Census of Boston for 1845 by Lemuel Shattuck, Boston, 1846, and are "an abstract from the Printed Bills of Mortality."

Subsequent data are taken from the last annual report of the Boston Board of Health.

In the early records "typhus fever" and "typhoid fever" were confounded. The records also contain references to "fever," to "intermittent fever," "remittent fever," etc., many of which were doubtless typhoid fever, and which, if included, would make the figures from 25 to 50% more than those given in the table under "typhus fever."

TABLE V.—TYPHOID FEVER STATISTICS, CHICAGO, ILL., ILLUSTRATING A COMMON METHOD OF REPORTING STATISTICS, AND ALSO SHOWING SEASONAL DISTRIBUTION.

(From Annual Reports of the Department of Health.)

Years.	Number of Typhoid Deaths by Months.													Typhoid Fever Mortality.		Annual Death-rates from all Causes per 1000 of Population.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Percentages of Total Mortality.	Per 100,000 of Population.	
1857	1	3	4	4	8	2	4	8	17	11	13	7	82	3.40	93.6	27.56
1858	7	5	4	6	6	4	1	2	7	4	1	2	49	2.17	54.4	25.06
1859	2	1	8	2	4	2	1	3	9	9	3	7	51	2.54	54.8	21.59
1860	3	2	3	6	...	...	2	6	3	15	3	3	46	2.03	42.1	20.73
1861	5	4	5	6	9	4	8	7	2	8	7	9	74	3.25	61.7	18.99
1862	6	5	2	3	4	3	8	9	13	11	15	6	85	3.00	61.5	20.52
1863	14	35	12	7	6	6	4	5	25	10	10	15	149	3.58	99.3	25.83
1864	24	18	24	9	9	10	5	18	23	21	14	17	192	4.32	113.4	26.26
1865	13	8	14	16	9	7	15	17	20	25	26	20	190	4.72	106.4	22.57
1866	21	12	9	9	12	13	18	14	35	38	18	4	203	3.11	101.3	32.55
1867	11	10	5	15	5	15	9	13	18	25	26	13	165	3.46	73.3	21.21
1868	14	7	11	7	5	8	10	29	32	37	21	19	200	3.34	79.3	23.74
1869	6	7	7	7	12	12	17	17	22	38	29	9	183	2.82	65.4	23.17
1870	6	8	16	8	8	10	14	38	58	49	35	18	268	3.66	87.4	23.88
1871	8	7	8	9	10	...	12	...	...	18	75	57	204	2.92	61.0	20.87
1872	19	11	13	12	19	10	17	94	140	107	49	33	524	5.16	142.6	27.64
1873	17	8	6	11	12	13	12	31	52	55	38	17	272	2.85	71.6	25.15
1874	13	11	11	11	5	7	10	28	33	36	25	21	211	2.63	53.4	20.30
1875	11	8	10	10	9	4	12	19	46	44	17	17	207	2.62	51.7	19.72
1876	...	...	...	...	...	...	...	...	...	...	...	...	168	1.96	41.2	21.03
1877	7	9	11	2	5	7	19	16	30	25	20	8	159	1.98	37.0	18.67
1878	6	10	9	9	6	6	17	16	25	17	15	10	146	1.97	33.4	16.99
1879	12	13	11	7	11	14	8	33	33	30	17	19	208	2.41	42.3	17.53

TABLE V.—*Continued.*

Years.	Number of Typhoid Deaths by Months.													Typhoid Fever Mortality.		Annual Death-rates from all Causes per 1000 of Population.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Percentages of Total Mortality.	Per 100,000 of Population.	
1880	7	10	8	11	8	10	11	22	26	31	14	13	171	1.63	34.0	20.79
1881	13	15	13	10	29	24	23	98	94	123	73	53	568	4.03	105.2	26.11
1882	62	39	25	15	26	16	26	52	59	66	38	38	462	3.49	82.4	23.60
1883	22	13	17	16	13	17	23	50	44	41	45	60	361	3.12	62.2	19.92
1884	42	26	13	18	19	23	22	48	36	39	34	34	354	2.84	56.2	19.80
1885	33	14	17	21	38	32	79	67	91	33	39	32	496	3.98	74.6	18.76
1886	19	23	35	45	37	30	36	57	54	66	52	29	483	3.53	68.6	19.47
1887	26	24	41	35	23	13	35	48	41	40	38	18	382	2.48	50.3	20.27
1888	21	20	9	19	19	16	32	50	60	46	40	43	375	2.38	46.7	19.65
1889	30	21	15	12	16	18	29	64	77	68	68	35	453	2.67	48.4	18.12
1890	53	136	103	45	82	107	86	115	95	72	67	47	1008	4.61	91.6	19.87
1891	67	61	71	136	408	167	200	182	198	171	150	186	1997	7.20	173.8	24.16
1892	311	187	76	56	70	55	211	179	138	92	67	47	1489	5.68	124.1	21.85
1893	41	30	41	58	56	60	55	76	86	81	43	43	670	2.47	53.5	21.61
1894	46	26	27	30	31	31	37	52	71	68	38	34	491	2.06	37.5	18.26
1895	30	21	26	30	30	18	36	59	76	90	60	42	518	2.14	37.9	17.72
1896	87	89	65	33	31	44	58	64	87	89	60	44	751	3.23	52.6	16.29
1897	38	46	41	19	13	23	27	42	48	61	44	35	437	2.00	29.3	14.63
1898	29	32	41	94	67	35	55	45	65	62	56	55	636	2.79	40.8	14.64
1899	44	24	18	23	25	28	41	62	58	44	43	32	442	1.73	27.2	15.68
1900	23	14	27	23	19	17	26	34	34	38	39	43	337	1.35	19.8	14.68
1901	26	16	15	20	24	9	55	83	74	102	54	31	509	2.09	29.0	13.89
1902	21	14	20	16	24	22	44	193	165	78	72	132	801	3.03	44.1	14.57
1903	97	55	49	33	26	21	29	59	82	45	56	36	588	2.03	31.4	15.43
1904	30	33	34	35	24	18	28	34	36	33	32	36	373	1.42	19.3	13.62
1905	29	15	24	19	16	24	27	39	32	43	22	39	329	1.21	16.1	13.67
1906	27	19	28	34	29	29	20	29	49	37	39	30	370	1.27	18.1	14.18

TABLE IV. — TYPHOID FEVER DEATH-RATES IN CERTAIN CANADIAN CITIES PER 100,000.

(Compiled for the Author by R. S. Lea, Consulting Engineer, Montreal.)

Years.	Montreal.	Quebec.	St. Louis.	Sherbrooke.	Ottawa.	Toronto.	Hamilton.	London.	Kingston.	Brantford.	Winnipeg.
1880	...	...	...	...	...	44.3	48.5	...	35.6	...	...
1881	...	...	...	...	10.9	66.1	64.0	20.2	42.6	...	...
1882	...	...	...	...	73.0	70.6	47.2	112.0	49.7	...	...
1883	...	...	...	...	84.0	80.9	30.5	52.3	33.1	...	...
1884	...	...	...	...	51.8	63.0	38.2	62.1	39.2	33.8	...
1885	...	...	...	...	12.2	58.6	20.0	26.6	26.5	41.2	...
1886	...	...	...	...	34.5	45.7	26.4	53.7	12.6	47.8	...
1887	...	...	...	...	105.0	61.1	46.2	22.3	37.0	63.9	...
1888	...	...	...	...	37.5	51.8	30.9	29.8	24.7	76.5	...
1889	...	...	...	...	41.1	40.5	36.0	11.3	63.5	97.0	...
1890	...	...	...	...	40.3	93.5	28.6	26.1	60.2	63.0	...
1891	...	...	...	...	30.9	93.9	24.5	38.8	67.3	94.2	...
1892	...	...	...	...	24.6	42.0	28.2	43.3	71.9	7.8	...
1893	...	...	...	...	37.6	39.5	10.0	27.5	25.4	38.5	...
1894	...	...	...	...	39.5	23.4	17.8	21.2	20.2	68.4	8.6
1895	...	...	...	...	47.8	28.9	23.5	37.1	79.4	120.0	0
1896	21.5	20.5	...	62.9	34.5	24.5	27.2	21.5	59.0	...	7.9
1897	31.9	22.1	...	71.1	51.2	18.2	9.6	24.3	24.5	66.5	12.9
1898	25.3	11.0	...	43.8	42.3	16.0	13.3	36.0	53.1	65.9	48.3
1899	20.6	14.3	...	17.0	52.1	20.3	31.9	14.9	14.4	137.0	29.8
1900	46.7	7.3	0	16.8	38.4	20.1	30.4	26.3	22.3	78.0	164.5
1901	50.2	13.1	18.2	34.0	21.7	17.8	19.0	15.8	39.0	36.1	125.2
1902	34.0	10.1	17.4	16.7	31.3	14.3	18.8	0	5.5	35.8	95.2
1903	42.6	12.7	7.1	49.4	9.5	18.2	7.6	7.8	99.5	36.0	109.3
1904	50.5	9.8	50.7	31.3	19.8	25.8	16.8	42.5	22.1	50.0	248.5
1905	22.4	11.2	90.6	31.9	20.7	18.7	23.9	24.6	38.5	10.8	222.8
1906	48.7	8.3	66.4	33.8	33.6	31.4	34.8	36.2	38.4	52.8	152.2
1907	...	...	...	...	...	...	...	...	...	...	50.0

Population Estimates for 1906.

Montreal	312,923	London	41,397
Toronto	222,903	St. Louis	19,660
Winnipeg	101,000	Brantford	18,973
Ottawa	74,342	Kingston	18,218
Quebec	72,034	Sherbrooke	12,759
Hamilton	54,562		

TABLE V. — TYPHOID FEVER STATISTICS OF LONDON, BERLIN, PARIS AND VIENNA, FOR 1880–1905.

(From Annual Report of Boston Board of Health.)

Years.	London.			Paris.			Berlin.			Vienna.		
	Population.	Deaths.	Death-rate per 100,000.	Population.	Deaths.	Death-rate per 100,000.	Population.	Deaths.	Death-rate per 100,000.	Population.	Deaths.	Death-rate per 100,000.
1880	3,771,139	702	18.6	...	2,003	90.8	1,123,749	527	46.8	721,016	171	23.7
1881	3,824,960	977	26.3	2,239,938	1,955	87.5	1,158,539	352	30.5	741,208	171	23.1
1882	3,861,876	975	25.9	...	3,214	143.5	1,196,205	357	29.9	749,919	187	24.9
1883	3 901,164	935	24.0	...	1,880	83.7	1,232,716	222	18.0	750,762	157	20.9
1884	3,939,832	936	23.8	...	1,503	66.8	1,271,677	243	19.2	759,849	95	12.5
1885	3,978,883	585	14.8	...	1,320	58.7	1,315,656	214	16.3	769,889	106	13.8
1886	4,018,321	618	15.4	2,260,945	954	42.2	1,363,031	181	13.3	780,066	85	10.9
1887	4,058,150	612	15.3	...	1,385	60.4	1,415,269	193	13.6	790,381	80	10.1
1888	4,098,374	694	15.1	...	756	32.5	1,472,151	188	12.8	800,836	107	13.4
1889	4,138,996	528	12.8	...	1,008	42.7	1,528,721	290	19.0	811,434	103	12.7
1890	4,180,021	618	14.8	...	665	28.2	1,579,524	143	9.1	822,176	77	9.4
1891	4,221,452	547	13.0	2,424,705	549	22.7	1,601,327	166	10.4	1,378,530	85	6.2
1892	4,263,294	486	11.4	...	691	28.0	1,656,715	137	8.3	1,406,933	116	8.3
1893	4,306,411	719	16.7	...	570	22.8	1,714,938	161	9.4	1,435,931	105	8.0
1894	4,349,166	635	14.6	...	697	27.4	1,655,235	69	4.2	1,465,637	74	5.1
1895	4,392,346	614	14.0	...	274	10.6	1,677,304	95	5.7	1,495,764	86	5.8
1896	4,421,955	591	13.4	2,511,629	262	10.1	1,695,313	80	4.7	1,526,623	79	5.2
1897	4,463,169	593	13.3	...	249	9.7	1,758,885	71	4.0	1,551,129	84	5.4
1898	4,504,766	585	13.0	...	256	9.9	1,805,054	78	4.3	1,590,295	93	6.8
1899	4,506,752	801	17.8	...	754	29.0	1,817,952	74	4.1	1,623,134	66	4.1
1900	4,589,129	756	16.5	...	912	34.6	1,864,203	109	5.8	1,656,662	137	8.3
1901	4,544,983	548	12.1	2,660,494	363	13.7	1,891,900	88	4.7	1,691,996	76	4.5
1902	4,579,110	585	12.8	...	...	...	1,920,459	52	2.7	1,726,604	51	3.0
1903	4,613,812	396	8.6	...	280	10.4	1,955,875	63	3.2	1,744,177	68	3.9
1904	4,649,038	297	6.2	...	334	12.2	2,040,455	75	3.7	1,797,992	60	3.4
1905	4,684,794	246	5.2	...	...	...	2,043,385	109	5.3	1,897,630	83	4.4

TABLE VI. — TYPHOID FEVER DEATH-RATES IN CERTAIN CITIES OF FRANCE.

(After Debauve-Imbeaux.)

Name of City.	Population in 1901.	Typhoid Fever Death-rate per 100,000.		
		1886–1889	1890–1898	1899–1903
Paris	2,714,068	45.2	20.0	19.3
Lille	210,069	19.5	13.7	09.8
Roubaix	124,365	27.0	23.5	17.2
Rheims	108,385	44.2	30.4	28.6
Nancy	102,559	55.7	57.4	31.2
Lyon	459,099	29.5	23.8	21.1
Saint-Etienne	146,559	28.7	28.0	23.9
Marseille	491,161	104.2	67.3	40.7
Toulon	102,118	106.2	109.2	95.9
Nice	105,109	85.7	51.8	30.7
Toulouse	149,841	80.2	35.8	24.8
Bordeaux	256,638	62.0	28.2	17.4
Rouen	116,316	72.5	68.2	40.6
Le Havre	130,196	195.5	98.2	87.0
Nantes	132,990	51.7	48.1	36.2
Total for 56 cities of France	7,521,151	52.1 For the year 1886.		21.2 For the year 1903.

TABLE VII. — TYPHOID FEVER DEATH-RATES FOR CERTAIN GERMAN CITIES PER 100,000.

Year.	Berlin.	Hamburg.	Breslau.	Munich.	Dresden.	Leipsig.	Cologne.	Frankfort.	Königsberg.	Hanover.	Stuttgart.	Bremen.
1885	16.3	34.0	21.3	17.2	13.8	15.9	13.1	13.0	42.4	9.3	7.2	6.8
1886	13.3	65.3	16.9	19.7	17.8	8.2	12.4	12.3	41.2	16.6	8.5	9.2
1887	13.6	85.9	15.6	9.3	10.8	9.0	11.9	6.1	41.9	6.6	6.8	6.6
1888	12.8	52.2	14.6	9.8	9.8	6.7	9.4	8.3	80.9	10.4	8.2	6.5
1889	19.0	41.0	11.2	9.4	7.7	11.3	16.7	8.6	17.5	11.8	6.5	5.9
1890	9.1	26.2	14.8	8.0	7.6	11.8	8.5	7.8	16.1	7.3	2.1	9.5
1891	10.4	26.2	11.4	6.6	7.9	15.1	13.1	5.8	22.7	5.2	7.0	13.2
1892	8.3	34.5	14.8	2.9	5.3	8.0	11.4	7.5	13.8	6.1	4.7	9.8
1893	9.4	17.6	9.8	14.8	4.8	7.0	18.3	4.4	13.7	8.0	8.6	17.7
1894	4.2	6.0	6.8	2.5	8.0	9.7	6.7	6.3	16.4	7.2	5.8	5.8
1895	5.7	9.2	9.9	3.6	5.1	8.3	8.4	5.2	8.1	6.4	4.4	6.3
1896	4.7	5.4	7.1	3.2	4.3	7.6	5.8	4.5	16.0	6.8	6.2	7.5
1897	4.0	7.1	10.9	5.1	3.3	9.0	8.5	5.1	10.1	3.6	1.2	3.1
1898	4.3	4.6	6.9	3.3	4.3	8.1	11.4	1.5	9.9	5.8	3.7	4.4
1899	4.1	3.7	22.8	3.1	7.3	7.6	8.6	3.7	13.0	7.7	3.1	...
1900	5.8	3.4	10.6	...	4.1	...	...	...	...	...	4.3	...
1901	4.7	...	...	...	6.4	...	...	...	...	...	...	...
1902	2.7	...	...	...	4.0	...	...	...	...	...	...	3.5
1903	3.2	...	...	...	5.3	...	...	...	...	...	...	...
1904	3.7	...	...	...	2.8	...	...	...	...	...	...	...
1905	5.3	...	...	...	3.7	3.2	...	...	...	...	...	3.7

TABLE VIII. TABLE SHOWING THE NUMBER OF DEA
WHICH HAVE A POPULATION OF

Cities.	Population.							
	1880	1890	1900	1905	1880	1881	1882	1883
Allegheny, Pa.	78,582	105,287	129,896	142,848*	44	98	116	61
Baltimore, Mo.	332,313	434,439	508,957	546,217	196	197	165	26
Boston, Mass.	362,839	448,477	560,892	595,380	154	207	212	98
Buffalo, N. Y.	155,134	255,665	352,387	372,088	...	110	121	63
Chicago, Ill.	503,185	1,099,850	1,698,575	1,932,315	171	568	462	361
Cleveland, Ohio	160,146	261,353	381,768	425,632	70	169	122	123
Columbus, Ohio	51,647	88,150	125,560	142,105	...	...	...	...
Denver, Colo.	35,629	106,713	133,859	150,317*	...	...	...	...
Detroit, Mich.	116,340	205,876	285,704	325,563*	...	...	...	...
Fall River, Mass.	48,961	74,398	104,863	105,762	35	32	51	33
Indianapolis, Ind.	75,056	105,436	169,164	212,198*	...	...	...	...
Jersey City, N. J.	120,722	163,000	206,433	232,699	31	79	156	65
Kansas City, Mo.	55,185	132,716	163,752	179,272*	...	...	...	...
Los Angeles, Cal.	11,183	50,395	102,419	200,000	...	...	...	...
Louisville, Ky.	123,151	161,129	204,731	222,660*	81	135	119	58
Memphis, Tenn.	33,592	64,495	102,320	121,235*	...	...	...	24
Milwaukee, Wis.	115,587	204,468	285,315	312,948*	43	59	42	35
Minneapolis, Minn.	46,887	164,738	202,718	261,974*	...	...	...	...
Newark, N. J.	136,508	181,830	246,070	283,289	72	51	97	89
New Haven, Conn.	62,882	81,298	108,027	119,027*	18	24	24	33
New Orleans, La.	216,090	242,439	287,104	309,639*	...	66	74	51
New York, N. Y.	1,897,712	2,487,840	3,437,202	4,000,403*	...	...	...	...
Manhattan	1,164,673	1,441,216	1,850,093	2,102,928	372	594	516	625
Bronx	41,626	74,085	200,507	271,592		The figu		
Brooklyn	599,495	838,547	1,850,093	1,355,106	71	99	93	92
Queens	52,927	82,299	152,999	197,838	...	...	...	...
Richmond	38,991	51,693	67,021	72,939	...	...	...	...
Omaha, Neb.	30,518	140,452	102,555	120,565*	26	32	38	20
Paterson, N. J.	51,031	78,347	105,171	111,529	...	...	...	...
Philadelphia, Pa.	847,170	1,046,964	1,293,697	1,850,093	498	645	650	579
Pittsburg, Pa.	156,389	238,617	321,616	364,161	211	248	268	188
Providence, R. I.	104,857	132,146	175,597	198,635*	53	38	140	128
Rochester, N. Y.	89,366	133,896	162,608	182,022	21	26	30	39
San Francisco, Cal.	233,959	298,997	342,782	364,677	83	90	152	163
Scranton, Pa.	45,850	72,215	102,026	116,111*	12	20	12	26
St. Joseph, Mo.	32,431	52,324	102,979	115,479*	...	...	...	...
St. Louis, Mo.	350,518	451,770	575,238	636,973*	139	191	166	158
St. Paul, Minn.	41,473	133,156	163,065	191,023	36	91	80	60
Syracuse, N. Y.	51,792	88,143	108,374	117,129*	...	...	...	...
Toledo, Ohio	50,137	81,434	131,822	155,887	18	21	...	20
Washington, D. C.	177,624	230,392	278,718	302,883*	95	153	123	118
Worcester, Mass.	58,291	84,655	118,421	128,135	31	21	28	18
Cincinnati, Ohio	296,908	255,139	325,902	341,444	178	183	146	136

* *U. S.* Census Estimate.

OID FEVER STATISTICS.

OM TYPHOID FEVER IN THE CITIES OF THE UNITED STATES OR OVER FOR THE YEARS 1880 TO 1906.

Deaths from Typhoid Fever by Years.

86	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906
8	110	106	106	146	96	171	161	99	227	59	79	73	135	121	135	149	124	166	182	187
0	156	161	191	247	150	193	224	222	173	188	189	189	153	189	141	220	189	199	197	183
5	183	170	186	155	154	137	148	141	163	162	173	185	165	143	142	139	119	135	117	122
1	77	68	73	105	129	98	112	185	87	68	69	98	87	90	98	125	133	91	90	90
3	382	375	453	1008	1997	1489	670	491	518	751	437	636	442	337	509	801	588	373	329	370
3	120	113	185	180	137	167	153	89	117	143	79	121	118	205	140	133	472	204	67	93
.	...	...	36	65	48	45	46	47	56	49	29	33	31	53	47	44	46	195	109	52
7	101	134	188	287	99	64	71	59	43	91	63	41	49	43	48	65	60	45	52	98
7	116	86	62	39	73	209	97	67	56	57	38	58	35	50	58	60	53	50	45	70
0	45	46	48	209	49	27	62	33	30	25	32	21	11	15	21	14	27	19	11	9
.	...	...	...	...	...	52	110	56	140	80	64	65	74	79	63	88	108	122	412	75
8	81	114	132	159	167	123	116	96	174	158	38	79	39	44	33	44	36	46	45	45
.	...	...	...	...	...	...	...	...	...	...	...	41	...	60	71	60	132	70	98	52
.	...	35	37	19	28	22	36	43	31	28	25	44	41	47	33	44	53	54	54	45
7	120	133	144	142	130	116	135	145	126	131	93	126	132	106	104	108	157	112	113	137
5	42	45	37	35	45	21	22	41	32	32	28	23	39	36	44	34	45	55	34	34
1	55	78	55	83	71	66	80	60	63	46	31	46	47	59	63	48	54	43	68	95
.	...	156	114	65	100	84	146	101	86	67	157	89	77	79	132	65	101	103	55	87
5	84	76	131	194	134	153	63	43	43	61	44	31	85	25	53	50	61	38	40	53
5	24	38	24	24	18	26	28	28	32	28	25	36	30	28	107	43	42	31	49	63
0	34	46	41	50	59	51	39	76	113	90	141	184	155	114	141	135	119	111	101	95
.	...	...	...	...	...	...	...	...	...	...	...	676	546	718	728	764	653	661	649	639
3	421	364	397	352	384	400	381	326	322	297	299	353	278	342	380	365	317	277	273	325
Bronx are included in those for Manhattan												23	16	30	32	34	33	32	37	44
3	143	153	161	182	180	162	179	159	173	163	173	270	205	301	272	322	267	303	297	230
.	...	...	...	...	...	...	...	...	...	...	...	16	27	32	27	32	22	34	31	30
.	...	...	...	...	...	...	...	...	...	...	...	14	20	13	16	11	14	15	11	10
8	97	63	46	50	28	19	22	40	29	18	22	32	26	24	23	20	11	19	32	48
8	16	...	19	18	18	15	33	28	21	47	49	35	34	49	27	36	24	7	16	6
8	621	785	736	666	683	440	450	370	469	402	401	639	948	449	444	588	744	957	684	1063
0	269	191	218	315	249	256	292	152	213	175	184	218	342	464	416	475	474	503	380	519
3	39	103	59	39	62	51	50	70	46	40	24	39	42	41	47	36	37	28	35	39
3	38	54	39	43	50	71	58	18	43	26	35	19	32	30	31	19	21	29	19	31
5	64	93	160	133	128	99	99	118	108	85	62	136	74	46	77	98	10	100	91	...
7	9	31	20	18	28	33	24	21	33	24	15	14	25	32	24	18	13	13	22	64
.	...	...	...	...	...	17	...	22	19	28	22	...	...	14	12	14	9	9	10	10
4	116	133	140	137	172	514	171	172	100	118	119	99	149	168	198	222	287	215	124	112
8	145	135	101	74	65	57	59	37	41	43	25	41	32	39	24	24	18	27	20	41
4	20	27	22	29	40	33	34	41	31	30	24	45	26	31	20	10	6	12	18	11
9	23	25	28	38	23	35	25	31	40	37	37	31	40	51	40	52	40	56	71	70
1	167	188	213	257	186	216	202	228	235	148	130	191	199	220	172	226	140	135	140	161
5	13	2	25	15	18	19	31	31	25	14	15	13	19	32	26	18	17	5	27	15
1	403	203	142	205	186	121	134	169	120	164	101	105	121	119	182	206	150	270	155	239

TABLE

TABLE SHOWING THE NUMBER OF DEATHS FROM TYPHOID
POPULATIONS BETWEEN 50,000 AND 1

Cities.	Population.										
	1880	1890	1900	1905	1880	1881	1882	1883	1884	1885	188
Albany, N. Y.	30,752	94,923	94,151	79,848*	...	...	...	...	38	52	9
Atlanta, Ga.	37,409	65,533	89,872	102,702*	25	68	53	79	51	41	29
Bridgeport, Conn.	27,649	48,866	70,996	82,061*	10	13	9	2	11	12	[illegible]
Cambridge, Mass.	52,669	70,028	91,886	96,324	10	21	17	16	24	16	21
Camden, N. J.	41,659	58,313	75,935	81,877	25	32	50	39	34	43	41
Charleston, S. C.	49,984	54,955	55,807	56,147*	56	57	53	56	43	29	35
Dayton, Ohio	38,678	61,220	85,333	98,350	14	37	12	18	19	20	17
Des Moines, Iowa	22,408	50,093	62,139	75,626*	...	...	...	...	...	...	...
Duluth, Minn.	838	33,115	52,969	64,942*	...	...	...	...	...	...	...
Elizabeth, N. J.	28,229	37,764	52,130	60,509	6	8	7	13	13	10	9
Erie, Pa.	27,737	40,634	52,733	58,783*	4	17	19	6	6	10	11
Evansville, Ind.	29,280	50,756	59,007	63,132*	...	...	...	...	...	...	...
Grand Rapids, Mich.	32,016	60,217	87,565	97,756*	...	...	...	...	...	...	...
Harrisburg, Pa.	30,762	39,385	50,167	54,807*	...	...	...	...	...	...	...
Hartford, Conn.	42,015	53,230	79,850	93,160*	13	27	30	12	28	21	21
Hoboken, N. J.	30,999	43,648	59,364	65,468	8	7	27	14	24	21	2
Kansas City, Kas.	3,200	38,316	51,418	67,614*	...	...	...	...	...	...	...
Lawrence, Mass.	39,151	44,654	62,559	70,050	27	49	31	28	19	17	2
Lowell, Mass.	59,475	77,696	94,969	94,889	22	54	50	49	41	49	5
Lynn, Mass.	38,274	55,727	68,513	77,042*	26	24	27	21	20	14	14
Manchester, N. H.	32,630	44,126	56,987	63,417*	...	...	47	20	17	20	12
Nashville, Tenn.	43,350	71,168	80,865	84,227*	58	38	27	31	43	...	22
New Bedford, Mass.	26,845	40,753	62,442	74,362	2	12	12	10	23	7	27
Oakland, Cal.	34,555	48,682	66,960	72,670*	20	...	...	...	12	12	13
Peoria, Ill.	29,259	41,024	56,100	65,026*	...	...	...	...	...	...	...
Portland, Me.	33,810	36,426	50,145	54,330*	...	...	...	...	...	...	...
Portland, Ore.	17,577	46,385	90,426	104,141*	...	...	...	...	...	...	...
Reading, Pa.	43,278	58,661	78,961	89,111*	...	...	24	18	16	14	22
Richmond, Va.	63,600	81,388	85,050	86,880*	39	72	52	52	120	51	27
Salt Lake City, Utah	20,768	44,243	53,531	58,914*	...	...	...	...	...	...	...
San Antonio, Tex.	20,550	37,673	53,321	61,146*	...	...	...	...	...	...	...
Savannah, Ga.	30,709	43,189	54,244	67,311*	...	...	...	...	...	...	...
Seattle, Wash.	3,533	42,837	80,671	99,586*	...	...	...	...	...	...	...
Somerville, Mass.	24,933	40,152	61,643	69,272	7	8	8	13	8	11	3
Springfield, Mass.	33,340	44,179	62,059	73,540	16	27	22	28	18	22	12
Trenton, N. J.	29,110	57,458	73,307	84,180	5	19	20	16	21	11	12
Troy, N. Y.	56,747	60,956	60,651	76,271*	...	...	...	...	12	35	48
Utica, N. Y.	33,914	44,007	56,383	63,647*	...	...	...	...	9	10	1
Wilkesbarre, Pa.	23,339	37,718	51,721	58,721*	...	...	...	...	...	...	...
Wilmington, Del.	42,478	61,431	76,508	83,860*	24	43	51	32	45	25	25

* U. S. Census Estimated.

IX.

FEVER IN THE CITIES OF THE UNITED STATES WHICH HAVE 00,000 FOR THE YEARS 1880 TO 1906.

Deaths from Typhoid Fever by Years.

1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906
71	74	77	62	108	50	58	52	162	97	84	94	82	38	20	29	19	18	19	20
68	105	48	99	80	74	63	50	68	68	55	56	77	52	66	83	37	61	72	66
17	8	8	3	8	7	12	2	6	11	14	8	8	10	18	18	11	14	9	10
20	27	25	17	16	15	16	27	12	30	11	14	20	15	10	17	14	23	12	11
50	55	90	82	33	38	38	42	64	32	38	23	49	16	9	16	8	16	15	...
43	30	40	56	28	27	24	24	33	44	40	73	61	42	48	44	35	33	29	45
18	15	18	12	19	28	46	50	57	47	18	18	31	26	23	35	21	17	22	18
...	...	...	...	...	...	22	29	30	14	20	17	13	7	22	21	...	...	...	...
...	78	48	42	71	41	53	70	101	112	43	34	22	62	35	32	40	39	32	32
7	12	9	20	5	11	8	10	14	8	7	7	5	5	15	15	13	9	6	11
7	9	19	29	30	24	15	17	21	19	13	8	18	18	8	13	17	27	11	29
40	32	35	39	51	29	35	34	96	27	16	13	33	29	27	24	17	25	21	22
...	...	...	30	43	52	70	36	33	9	14	30	34	28	31	48	36	59	49	42
...	...	...	30	43	31	46	30	25	9	8	18	14	26	28	24	53	29	31	28
8	26	26	30	39	46	28	32	36	30	20	36	32	44	35	14	19	12	16	30
16	15	24	19	14	15	10	17	11	21	9	7	13	19	17	7	10	13	10	11
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
47	48	55	60	55	60	50	24	16	10	9	9	20	11	12	11	23	11	15	14
90	62	69	125	78	77	55	51	33	38	17	25	18	17	18	16	26	17	17	7
16	12	7	11	11	11	12	12	13	27	19	15	13	13	10	7	14	17	16	14
18	12	16	17	18	11	15	21	21	20	11	14	12	11	11	8	10	13	11	6
31	39	43	36	45	43	36	28	41	33	45	22	44	39	38	46	58	46	54	63
6	8	19	5	8	17	29	13	9	14	23	17	16	22	19	24	28	12	5	8
15	21	18	22	27	20	48	14	18	18	9	12	21	13	6	8	15	30	24	29
...	...	...	...	...	...	16	10	36	13	18	18	12	23	15	18	...	...	...	...
3	6	10	3	12	6	14	20	21	12	11	36	13	19	15	17	15	15	11	9
...	...	...	...	...	...	...	...	...	...	...	20	21	33	23	34	34	25	36	35
19	25	26	32	29	28	25	33	36	36	24	45	26	40	35	55	30	29	23	34
32	29	42	72	51	58	48	28	28	12	20	29	37	75	32	37	51	34	28	41
...	...	...	...	45	20	32	34	23	29	25	23	...	14	20	31	22	27	35	36
...	...	...	...	...	...	...	...	...	...	...	...	52	23	33	23	36	30	27	...
...	...	...	...	...	...	...	...	...	...	...	18	18	16	17	26	34	51	27	...
...	...	...	...	...	...	...	...	...	...	...	22	24	24	26	29	33	35	36	37
11	17	7	49	13	14	13	13	10	26	11	11	15	9	12	6	10	11	9	11
17	26	19	88	16	39	17	16	9	11	19	15	15	17	16	13	17	11	19	16
17	11	20	11	15	15	19	16	11	16	25	22	33	26	14	29	45	36	22	34
48	34	46	25	48	27	37	35	39	28	20	51	48	76	42	37	25	34	36	28
13	7	12	11	11	20	5	12	8	9	8	14	9	8	9	12	10	11	6	18
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19
37	32	30	55	35	29	44	29	27	15	23	29	46	36	32	41	54	43	32	34

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